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MANUFACTURING METHODS AND TECHNOLOGY. PROJECT SUMMARY REPORTS.(U)
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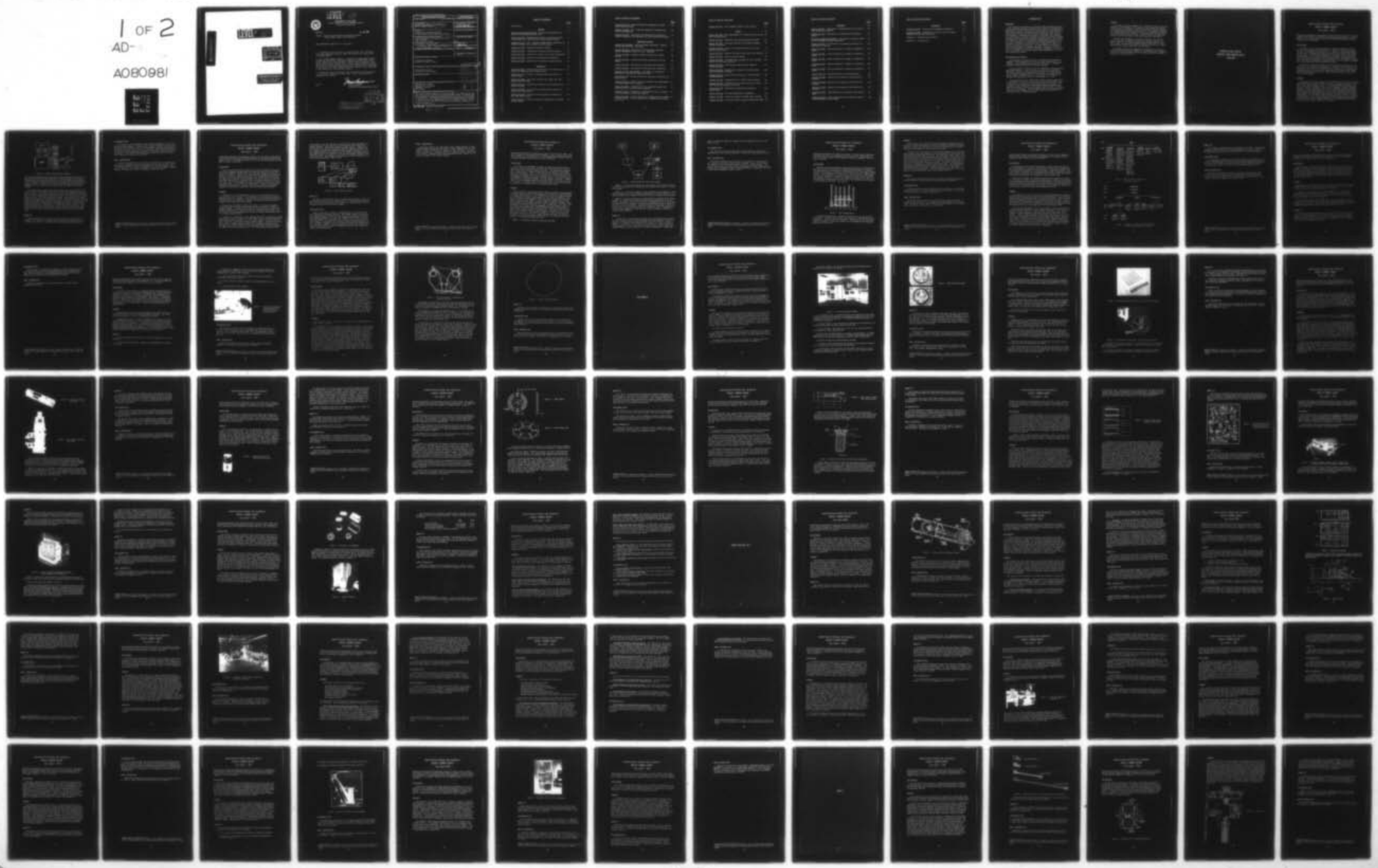

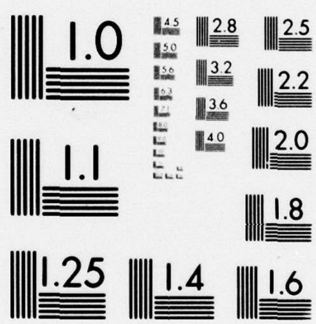

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DEPARTMENT OF THE ARMY
US ARMY INDUSTRIAL BASE ENGINEERING ACTIVITY
ROCK ISLAND, ILLINOIS 61299

DRXIB-MT 11 JAN 1980

SUBJECT: Manufacturing Methods and Technology Program
Project Summary Report (RCS DRCMT-302)

SEE DISTRIBUTION (Appendix II to Inclosure 1)

1. In compliance with AR 700-90, C1, dated 10 March 1977, the Industrial Base Engineering Activity (IBEA) has prepared the inclosed Project Summary Report.

2. This Project Summary Report is a compilation of MMT Summary Reports prepared by IBEA based on information submitted by DARCOM major subordinate commands and project managers. These projects represent a cross-section of the type of efforts that are being conducted under the Army's Manufacturing Methods and Technology Program. Persons who are interested in the details of a project should contact the project officer indicated at the conclusion of each individual report.

3. Additional copies of this report may be obtained by written request to the Defense Documentation Center, ATTN: TSR-1, Cameron Station, Alexandria, VA, 22314.

James W. Carstens
JAMES W. CARSTENS
Acting Director,
Industrial Base Engineering Activity

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REPORT DOCUMENTATION PAGE

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Manufacturing methods
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report contains summaries of 67 projects that were completed under the Army's Manufacturing Methods and Technology (MMT) Program. The MMT program was established to upgrade manufacturing facilities used for the production of Army materiel. The summaries highlight the accomplishments and benefits of the projects and the implementation actions underway or planned. Points of contact are also provided for those who are interested in obtaining additional information.

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INTRODUCTION

Background

The Manufacturing Methods and Technology (MMT) Program was established to upgrade manufacturing facilities used for the production of Army materiel, and as such, provides direct support to the Industrial Preparedness Program. The Manufacturing Methods and Technology Program consists of projects which provide engineering effort for the establishment of manufacturing processes, techniques, and equipment by the Government or private industry to provide for timely, reliable, economical, and high-quality quantity production means. The projects are intended to bridge the gap between demonstrated feasibility and full-scale production. The projects are normally broad based in application, are production oriented, and are expected to result in a practical process for production. The projects do not normally include the application of existing processes, techniques, or equipment to the manufacture of specific systems, components, or end items, nor do they apply to a specific weapon system development or a product improvement program.

MMT Program Participation

MMT Programs are prepared annually by DARCOM major subordinate commands. These programs strive for the timely establishment or improvement of the manufacturing processes, techniques, or equipment required to support current and projected programs.

Project proposals (Exhibits P-16) are submitted to the appropriate MMT Program Office. A list of offices is provided in Appendix I. Additional information concerning participation in the MMT Program can be obtained by contacting an office listed or by contacting Mr. James Carstens, AUTOVON 793-5113, or Commercial (309) 794-5113, Industrial Base Engineering Activity, Rock Island, IL 61299.

In anticipation of the lengthy DOD funding cycles, projects must be submitted in sufficient time for their review and appraisal prior to the release of funds at the beginning of each fiscal year. Participants in the program must describe manufacturing problems and proposed solutions in Exhibit P-16 formats (see AR 700-90, 4 August 1975, for instructions). Project manager offices should submit their proposals to the command that will have mission responsibility for the end item that is being developed.

Contents

This report contains summaries of 67 completed projects that were funded by the MMT Program. The summaries are prepared from Project Status Reports (RCS DRCMT-301) and Final Technical Reports submitted by organizations executing the MMT projects. The summaries highlight the accomplishments and benefits of the projects and the implementation actions under way or planned. Points of contact are also provided for those interested in obtaining additional information.

The MMT Program addresses the entire breadth of the Army production base and, therefore, involves many technical areas. For ease of referral, the project summaries are grouped into six technical areas. The technical areas are CAD/CAM, Electronics, Inspection and Test, Metals, Munitions, and Non-Metals.

The Summary Reports are prepared and published for the Office of Manufacturing Technology, DARCOM, by the Manufacturing Technology Division of the Army Industrial Base Engineering Activity, (IBEA) in compliance with AR 700-90, Cl.

COMPUTER AIDED DESIGN/
COMPUTER AIDED MANUFACTURING
(CAD/CAM)

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology projects R76 3145 and R77 3145 titled, "Computer Aided Speckle Composition Void Detection System (CAM)", was completed by the US Army Missile Research and Development Command in August 1978 at a cost of $390,000.

BACKGROUND

A reliable low cost testing method for composite structures used in shoulder fired weapon systems was needed. Defective composite structures can fail catastraphically; therefore, as a minimum, a one hundred percent nondestructive inspection was required for man-rated systems using composite materials. Prior efforts demonstrated techniques for flaw detection and assessment of flaw size and shape using an Optical Holographic Technique for composite structures with simulated flaws. The results of these prior efforts are documented in technical report, DDC AD A029454, generated by a pacing Materials Testing Technology project.

The Optical Holographic Technique was based upon the premise that the character of the surface displacements of a structure with a flaw are different when the structure is loaded than the character of the surface displacements when it is not loaded. Comparison of holograms of the loaded and unloaded flawed structure can reveal differences in the character of surface displacements.

SUMMARY

The objectives of this project were to develop low cost, rapid, computerized production techniques to detect, locate, and quantify flaws in missile launch tubes and motor cases. The system developed consisted of two parts: a) optical recording of data, and b) computer system for numerical analysis. Optical recording of the data was obtained by several methods depending on the required results. If only one-dimensional displacement data using speckle photography was desired, then a rotating mirror system was employed. Two dimensional data analysis utilized a vidicon TV camera system which was also used in whole field data analysis such as reflecting grid and Moire. An x-y film translation stage was common to both systems along with some of the computer interfaces. The computer-aided speckle analyzer with TV camera is depicted in Figure 1.

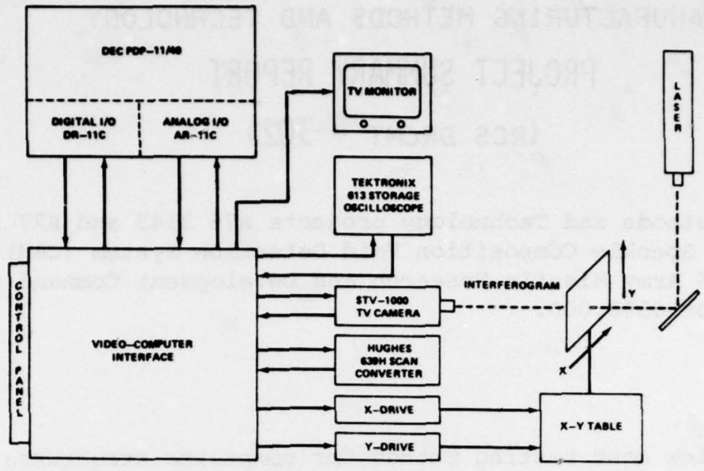

Figure 1 - Computer-aided Speckle Analyzer

The prototype nondestructive inspection system was developed with the capability of recording and analyzing speckle interferograms. The speckle interferograms are double exposed films. The first exposure was obtained with the component unloaded then the second exposure was obtained with the component loaded. The system utilized the shearing speckle techniques to determine if a flaw existed in the launch tube, and where the flaw was located.

The point-by-point method of Young's Fringes was used to determine the surface strain in the region of the flaw for use with standards for accept/reject criteria. The system could detect surface and subsurface flaws which cause a surface deformation as small as 0.0001 of an inch while the structure was under load. The system detects flaws which are not necessarily detrimental to the function of the component tested. Additional effort is needed to develop standards for accept/reject criteria. The optical techniques used by this system were demonstrated on composite structures. However, these techniques need not be limited only to composites, nor by the type of material, the density of the material, nor the shape of the material. One essential aspect for the use of this system is that the motion of deformation of the item under test should be parallel to the lens (in plane motion).

BENEFITS

Pending resolution of critical flaw size criteria, this inspection system has the potential to improve product quality and reliability, and to improve the ability to produce missile launch tubes and motor cases.

IMPLEMENTATION

The results of this MMT effort have not been implemented into the production of Army materiel. However, this inspection system is used at the US Army Missile Command in lieu of strain gauges to measure deformation on the order of .0001 to .07 of an inch. In several applications, deflection and strain data were obtained for composite structures loaded under static conditions. Full field strain analysis were obtained versus the single point contact with regular strain gauges.

MORE INFORMATION

Additional information on this effort is available in a technical report titled, "Computer Aided Optical Nondestructive Flaw Detection System for Composite Materials" dated 26 September 1977, DDC #AD A052674. The project officer is Mr. John A. Schaeffel, US Army Missile Command, Redstone Arsenal, AL 35809, AV 746-5692 or Commercial (205) 876-7465.

Summary Report was prepared by Stephen A. McGlone, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 273 9741 titled, "Manufacturing Methods and Technology Engineering Measure for CAD/CAM System: Drawing Symbol Library" was completed in March 1977 by the US Army Electronics Command at a cost of $167,794.

BACKGROUND

Prior to this MMT project, design of electronic equipment and generation of the equipment documentation were done separately at the US Army Electronics Command. Design effort for electronic equipment typically resulted in a piece of hardware and a documentation package which consisted typically of drawings and specifications. The documentation supplied at the completion of the end item development was usually done by a drafting department from sketches developed during the design process with the result that some of the documentation did not adequately describe the equipment piece parts. This project was undertaken to minimize the problem of inadequate documentation. Computer aided design systems and automated drafting and digitizing capabilities were provided by prior efforts.

SUMMARY

Integration of the documentation process into the design process was the objective of this effort. This integration should reduce the cost of designing electronic equipment. The MMT project developed and demonstrated a design method; its scope was limited to the design of printed circuit boards but the design method was generic.

This project consisted of four major tasks: a) procure an engineering drawing symbol storage and operating system, b) publish a catalog of standard symbols, c) generate and verify the standard symbol library with support documentation to display electronic and mechanical drawings, and d) interface the Drafting/Digitizing System to Computer Aided Design graphics via mass storage system.

A symbol is a collection of line segments which can be logically grouped and used as a group more than once. The symbol library concept modifies the simple definition of a symbol to allow a given symbol to be multi-defined. The result of this effort was a Design Symbols System , sketched in Figure 1, which links a standard symbols library to an automated drafting system. The supporting software consists of library maintenance, design assistance, and symbol resolving operating system. The Design Symbols System allows

the designer to use the library to translate part type into symbol, determine component layout and routing, and translate the symbols to a drafting pattern. The symbol resolving system, Figure 1, consists of disc storage (five million characters) and disc operating system. The disc operating system was written in Varian Assembly language. The Design Symbols System was designed to run in a batch mode; extensive software modifications are required to run the Design Symbols System in the interactive mode. The system was designed as a low cost alternate to a stand-alone Minicomputer CADCAM system.

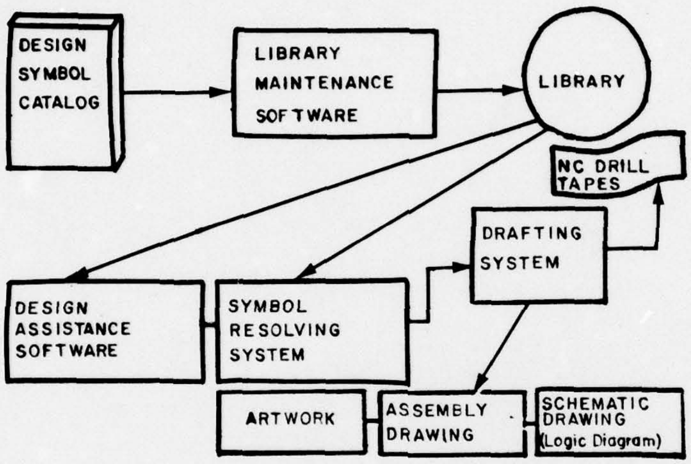

Figure 1 - Design Symbols System

BENEFITS

Software is available for use in a Design Symbol Library. This software has been used for design verification on an integrated printed circuit system and validation of master plates for several printed circuit boards at the US Army Electronics Command.

IMPLEMENTATION

There is presently no plan for implementation of the results from this technically successful project. The software system is available for implementation by either the Army Electronics Research and Development Command (ERADCOM) or by the Army Communications Research and Development Command at Ft. Monmouth, NJ. However, it may not be economically feasible to implement this software system because additional effort is needed to translate the disc operating system from Varian assembly language to FORTRAN. This translation would make the software portable and more readily useable by commercial printed circuit board designers and manufacturers.

MORE INFORMATION

The project officer for this effort is Mr. Thomas Wheeler, US Army Communications Research and Development Command, DRDCO-TCS-BG, Ft. Monmouth, NJ 07703, AV 995-2012 or Commercial (201) 544-2766. For additional information, a technical report is available titled, "Design Symbols Library, A Combined Design and Documentation Tool", Author - T. J. Wheeler, December 1976, DDC# AD A038620.

Summary Report was prepared by Stephen A. McGlone, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MAUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 276 9773 titled, "MMT - Computer Program Aid for Preparation of Automatic Analog Circuit Production Test Program" was completed by the US Army Communication Research and Development Command in June 1978 at a cost of $193,313.

BACKGROUND

This effort was undertaken to reduce the amount of direct labor required to prepare and validate programs used with Automatic Test Equipment (ATE) in the testing of analog circuits. The need became apparent during application of EQUATE (Electronic Quality Assurance Test Equipment) to Army radios. Prior to this effort, test programs were manually generated by engineers with a high investment in direct labor hours and considerable validation and fault isolation effort. This placed significant demands on available computer time and operator resources. Computer aides for test program preparation had been proven in the field of digital circuits. Successful work in the analog circuit field had been done by industry on a limited scale to satisfy specific needs.

SUMMARY

The objective of this project was to design, generate, and demonstrate a software processor which would automate the generation of test programs for linear analog circuits. The information flow in the system developed is illustrated in Figure 1 and consists of two types of software in support of Automatic Test Equipment (ATE) and uses an Abbreviated Test Language for all Systems (ATLAS). The two types of software are the ATE source program and the ATLAS Generator (AGEN) interactive program. These two programs are interrelated by two lists of parameters. The first list referred to is the list of input parameters that the operator inputs to the interactive program AGEN. AGEN performs necessary calculations on these inputs and then outputs the second list. The second list is comprised of the items used by the ATE program to determine if the network meets specifications. The function of AGEN is to fill the second list. Using these tests, the circuit's specifications and AGEN, the operator can produce a viable ATE source program which he can compile and run on station. A four phase approach was used.

PHASE I - The overall software system was designed.

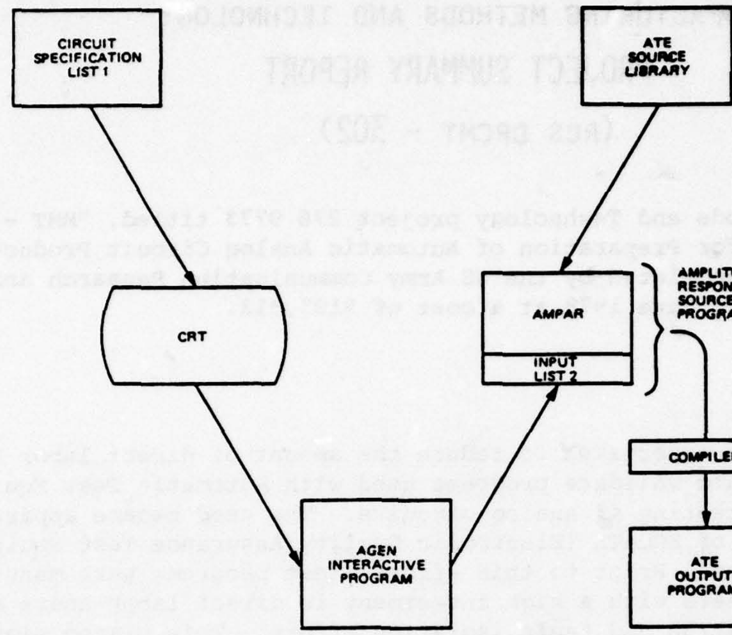

Figure 1 - AGEN Information Flow Block Diagram

PHASE II - The testing analysis for small signal linear analog circuits was defined specifically for amplifiers and oscillators in terms of a source test program.

PHASE III - Interactive computer aided techniques were generated so that required parameters could be obtained and passed to a source program. The source program can be compiled for execution on the Automatic Test Equipment.

PHASE IV - Software Processor was demonstrated by generating ATE source programs for twelve circuit characteristics with demonstration on an ATE system. The project resulted in an Analog Programming Aid which was written in FORTRAN IV and is portable. Although the generated version of AGEN covers only a few of the several hundred NSC (Network, Subcategory, Characteristic) codes, it can serve as a guide for future NSC code. Generation of an ATLAS type program for other NSC code can be an extension of AGEN by creating other branches.

BENEFITS

A comparison of the manhours required for an experienced Test Program Set (TPS) engineer using the manual system versus the manhours required to generate the same TPS using AGEN indicates a savings of 90% in a specific example. In addition to the reduction in manhour cost, AGEN provides assured quality of the test program by providing tested analysis algorithms, standardization of test techniques, and reduced maintenance. Additional

effort is needed to extend the capabilities for additional and more complex circuits.

IMPLEMENTATION

The effort has been continued under another project to extend the capabilities of the software processor to other more complicated circuits.

MORE INFORMATION

Additional information on this effort is available in a technical report titled "Final Report ATLAS Program Generator", April 1978, Contract No. DAAB07-76-C-8106, Harris Corporation, Author: Richard Savadel. The project officer for this effort is Mr. Roy Zelinka, US Army Communications Research and Development Command, ATTN: DRDCO-TCS-M, Ft. Monmouth, NJ, 07703 AV 992-5608 or Commercial (201) 532-5676.

Summary Report was prepared by Stephen A. McGlone, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 277 9832 titled, "Automatic Wire-wrap Verifier" was completed by the Harry Diamond Laboratories, US Army Electronics Research and Development Command in September 1978 at a cost of $30,000.

BACKGROUND

There are two major methods for providing electrical interconnections for discrete parts; printed-wiring boards and wire-wrapping. Although printed-wiring has an advantage for high-production and low-density applications, wire-wrapping is commonly used for short run, high complex digital circuits. Wire-wrapping is a process for interconnecting a large number (1000 is not unusual) of electronic components to form circuit functions. The assembly consists of a board with component sockets on one side and corresponding wire-wrap posts on the other. The components are connected by wire-wrapping the posts; see Figure 1.

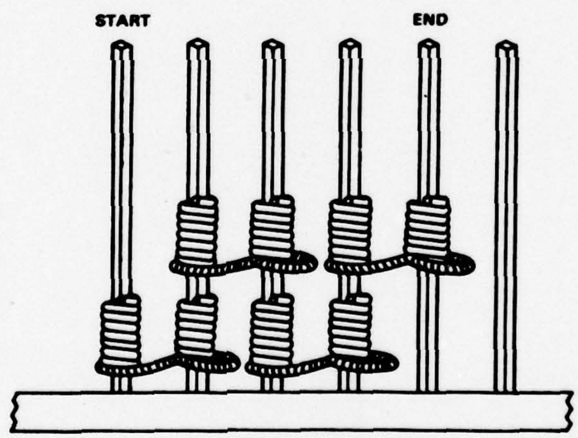

Figure 1 - Wire-wrapped posts.

A completed board usually consists of dense wire and a multitude of connections. Although care is taken, the wrapping of high-density boards is subject to error and is time consuming. To minimize wiring errors and speed up the process, numerical control (NC) semiautomatic wire-wrapping machines are often used.

SUMMARY

Wiring errors still occur with the semiautomatic wirewrapping equipment due to board misalignment, pin skew, or improper wrapping techniques. Manually checking the continuity of wiring for these boards is extremely expensive, time consuming, and usually not complete.

Th objective of this project was to develop software for an algorithm that could be used with automatic wire-wrap equipment to verify that complex panels have been properly wired. The algorithm allows a panel to be checked more rapidly than conventional manual methods. This not only reduces the time to test panels (thus increasing throughput times) but also allows checking for the presence of all required paths and checking to insure that no extra paths have been included. The manual method usually checks for the presence of required connections only. The algorithm has been totally implemented and the system is successful. The algorithm is implemented by the verification program producing a test tape that is used on the wire-wrap machine. The wire-wrap machine points to key posts while the operator performs visual and continuity tests.

BENEFITS

This project has provided a means of totally checking connections on wire-wrap boards in less time than incomplete manual techniques.

IMPLEMENTATION

A final technical report was prepared describing how to use the wire-wrapping equipment to verify connections via the algorithm. This method is being used at Harry Diamond Laboratories.

MORE INFORMATION

Additional information and a copy of the final technical report, "A Numerical Control Facility for Semiautomatic Wire-Wrapping and Verification", HDL-TM-79-20 dated August 1979 is available from Mr. Ira R. Marcus, HDL, AV 290-2820 or Commercial (202) 394-2820.

Summary Report was prepared by James H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 37T 3232 titled, "Computerized Production Process Planning" was completed by the US Army Missile Command in August 1979 at a cost of $100,047.

BACKGROUND

The spiraling costs of military systems in recent years not only reflects the effects of inflation, but also the high levels of technologiccal sophistication intrinsic to modern designs. These high system's costs have produced an awareness in recent years within DOD of the need to identify the high cost areas in the manufacturing of these systems and identify manufacturing technology (MT) programs to reduce system costs.

Quantitative methods for determining how MT money should be invested does not exist at MICOM. This project examined the potential for a quantitative methodology for assessing future MT programs. The work accomplished was directed toward identifying cost drivers for missiles and developing a methodology for forecasting high cost areas and technological opportunities that could be pursued to reduce high manufacturing costs.

SUMMARY

The objective of this project was to develop methodology for examining missile manufacturing costs, cost drivers in manufacture, and identifying future missile related manufacturing technology projects. Under contract, Battelle developed a missile parts classification system (MPCS). This system provides a methodology for examining cost drivers in missile manufacture plus a variety of other interactive possibilities achieveable through the availability of cost information at the discrete part level.

The MPCS was developed in "tree" form similar to other classification system such as MIL-STD-881A, "Work Breakdown Structure". The missile is initially divided into one of six sections: Structural System, Control, Guidance, Missile Assembly, Propulsion, and Test & Inspection; see Figure 1. Each of these sections is then subdivided over and over until all levels of breakdown yield discrete part data that reflect component characteristics such as material, physical size, performance characteristics, etc; see Figure 2. It was found that the amount of data generated in a fully developed MPCS is massive and therefore would necessitate a computer system to store, manipulate, and retrieve the data in order to use the information effectively and efficiently.

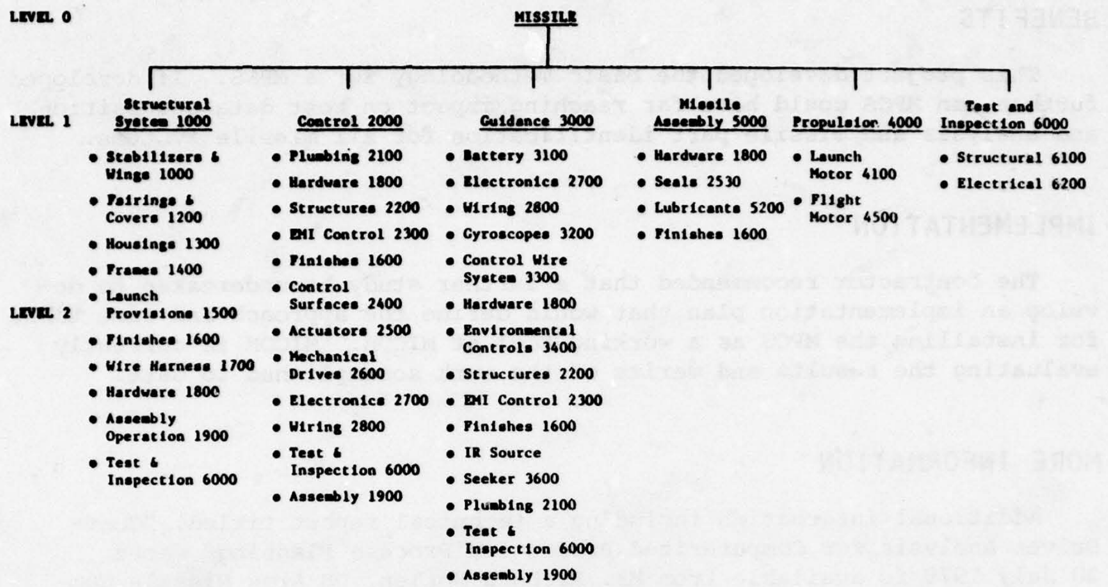

Figure 1 - MPCS for three levels and six major sections.

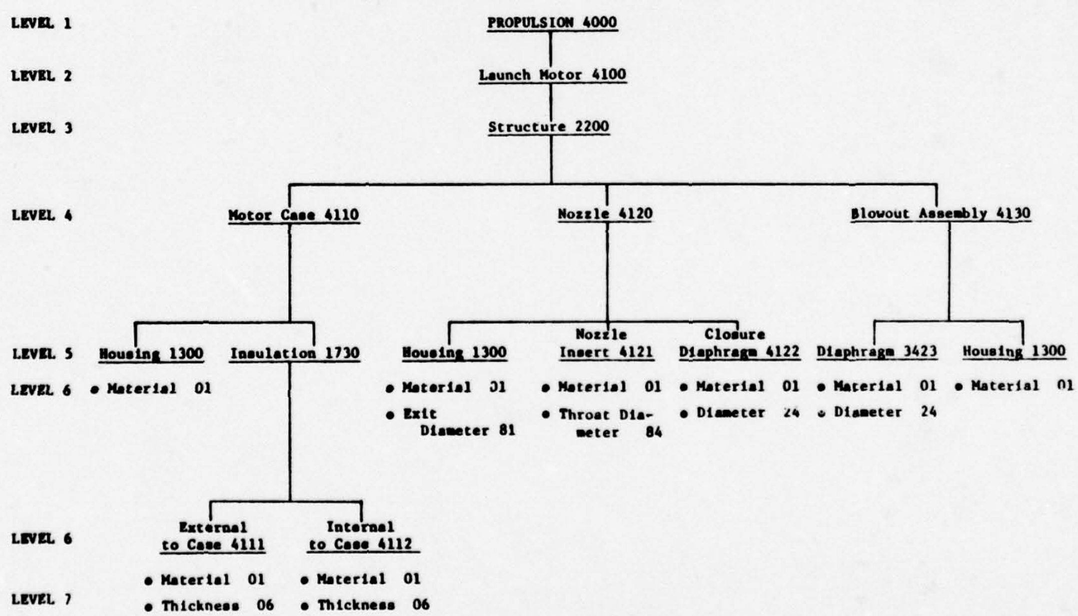

Figure 2 - Breakout through seven levels of one of the major sections in the MPCS.

BENEFITS

This project developed the basic methodology for a MPCS. If developed further, an MPCS could have far reaching impact on cost data acquisition and analysis and missile part identification for all missile systems.

IMPLEMENTATION

The contractor recommended that a further study be undertaken to develop an implementation plan that would define the approach and time table for installing the MPCS as a working tool at MICOM. MICOM is currently evaluating the results and merits of the work accomplished to date.

MORE INFORMATION

Additional information including a technical report titled, "Cost-Driver Analysis for Computerized Production Process Planning" dated 20 July 1979 is available from Mr. Richard Kotler, US Army Missile Command, AV 746-2065 or Commercial (205) 867-2065.

Summary Report was prepared by James H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 672 7157 titled, "Evaluation of Impact of N/C Upon Raw Material" was completed by the US Army Natick Laboratories in January 1975 at a cost of $100,000.

BACKGROUND

Quick reaction to mobilization can be hampered by excessive lead times required to procure castings or forgings. One alternative to procuring castings and forgings is to manufacture the item by hogging out a block of raw material using numerical controls (N/C). The purpose of this project was to determine the procedural and economic considerations which are faced when manufacture from casting or forgings is replaced by manufacture from a solid.

SUMMARY

The objectives of this project were to reduce procurement lead time by manufacturing critical items from solid stock rather than incur the procurement lead time of obtaining castings or forgings.

A total of 13 component parts, normally manufactured from forgings and castings, were N/C machined from solid bar stock on a Cincinnati - Heald 2253 Acracenter. Tapes were prepared using the APT language and post processed on a Univac 1106 computer.

For the items tested, it was shown to be cheaper and faster to manufacture by N/C machining from solids rather than conventional machining of castings or forgings. These results were dependent on the lot size and somewhat limited by the structural integrity of the end item.

BENEFITS

This study showed the feasibility of N/C machining items from solids rather than manufacturing the item from a forging or casting. Spin off benefits to Natick Laboratories included the establishment of a numerically controlled machining capability and an updating of local knowledge on production techniques and methods.

IMPLEMENTATION

The advantage of manufacturing components in limited quantities by N/C hogout from solid stock was demonstrated at Natick Laboratories. Fabrication, engineering, and designing personnel will use this knowledge in their choice of future manufacturing methods.

MORE INFORMATION

Additional information can be obtained from Mr. Michael Lynch, NARADCOM, AV 955-2211.

Summary Report was prepared by James Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 673 7265 titled, "Computer Controlled Reticle Engraving" was completed by the US Army Armament Materiel Readiness Command in July 1975 at a cost of $150,000.

BACKGROUND

A reticle is that element of an optical system containing the patterns of lines by which distances are computed, fire is directed and/or comparative locations are plotted. The patterns are engraved in the reticle by coating the reticle blank with a thin layer of acid-resistance wax then cutting the desired pattern into the wax. A pantograph machine is employed in this manual operation that traces up to ten reticles at a time. Once the pattern is cut into the wax, blank reticles are exposed to acid or acid fumes. Grooves are then etched into the exposed areas.

SUMMARY

The purpose of this project was to develop a new technique for engraving fire control reticles utilizing numerical control. The actual wax cutting operation was the only operation of concern.

A comprehensive review of reticle parameters were made and critical tolerances were specificed. In-house equipment was surveyed and evaluated but found to be unsuitable. A numerical controlled (NC) Bostomatic Precision Profiler, Model 10 A, was purchased and modified into a multistation scribing machine; see Figure 1. Tooling was designed and NC programming and system debugging accomplished. The resulting scribing system has the capability to scribe ten reticles via NC at one time.

BENEFITS

Five main benefits were derived as a result of applying NC to scribing lines:

a. The need for brass master templates was eliminated and replaced by NC tapes.

b. Previously, changes to reticle patterns required modifying the master template or machining a new one. With NC, changes are easily accommodated by changing the NC program.

c. The continuity of the reticle pattern has been increased by eliminating direct human control.

d. Errors related to operator dexterity and fatigue have been removed.

e. Scribing time has been reduced.

Figure 1 - Ten-Position Computer-Controlled Optical Scribing Machine in Production Use.

IMPLEMENTATION

The scribing system was used in production at Frankford Arsenal until that facility was closed down. Approximately 6500 reticles were scribed on the NC equipment thru August 1976. The equipment is now being used in the optical fabrication shop at ARRADCOM for prototype and R&D work.

MORE INFORMATION

Additional information is available from Mr. Harold Richardson, ARRADCOM, AV 880-3445 or Commercial (201) 328-5482.

Summary Report was prepared by James H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 674 7484 titled, "Application of Automatic Drafting Machine" was completed by Watervliet Arsenal in November 1976 at a cost of $100,000.

BACKGROUND

With prior year's funding, an Automatic Drafting Machine (ADM) was procured from Gerber Scientific Company. It consisted of three units: the series 2000 control, the operator station, and the Model 75 table. The series 2000 control in turn consisted of a digital computer for control, a hardware interface for matching the computer output to the ADM input, computer peripheral devices for data transfer, and a program for directing the operation of the system as an automatic drafting machine. Peripheral devices included a punched tape reader (data input), a tape punch (data output) and an ASR-33 teletypewriter for operator/system communication. An additional feature of the ADM was the optical linefollower with its support equipment and software which enabled the system to automatically follow and digitize a line of any contour. The ADM system, then, had a combined drafting and digitizing capability with potential applications in engineering design and manufacturing process support activities.

SUMMARY

The objective of this project was to extend the use and augment the capabilities of the ADM.

One immediate use of the ADM was in verifying N/C tapes. This had previously been done on the actual production machine by placing the new N/C tape in the machine control reader and, with a great deal of operator attention and intervention, and with the programmer standing by, cycling the machine through the programmed operation. The purpose of the procedure was to assure that the program tape would perform the operation completely and accurately and also to assure that no "wrecks" or machine/part interferences existed. Any errors discovered during verification necessitated the removal, return and correction of the tape, and rescheduling of verification on the production machine. This three to five hour procedure (not counting the delays due to error correction) could be performed in only a few minutes using the ADM with any needed tape corrections made immediately. See Figure 1 for an example of N/C tape verification. At the time of the technical report draft, over 200 tapes had already been verified on the ADM.

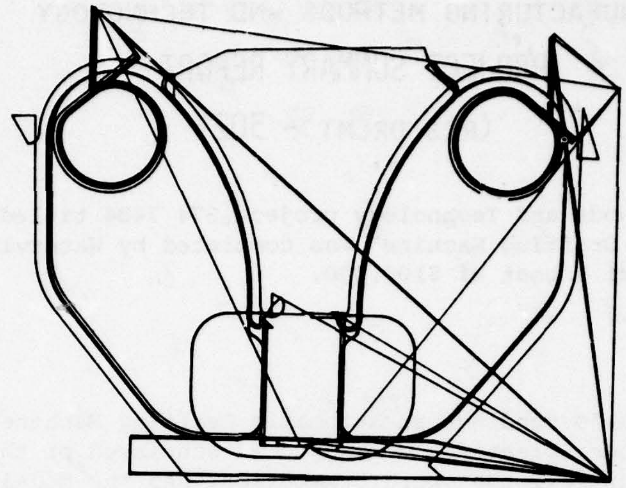

Figure 1 - N/C Verification - Centerline of cutting tool path

Programming the ADM with the drafting language supplied as part of the ADM software package turned out to be very time consuming; and since the control system had its own FORTRAN compiler, it was decided to develop all programs in FORTRAN for direct processing on the ADM.

Some examples of software developments were: a) the generation of cam path drawings from analytical data, see Figure 2, b) the generation of many profiles such as form tools, gears and comparator overlays, c) statistical analyses involving the plotting of data points and drawing the line of best fit (regression analysis), and d) preparation of vugraphs as visual aids in briefings, etc.

An opportunity to interface the ADM with the IBM 360-44 main computer occurred when the Computer Science Office obtained a Computer Graphics System (CGS) because one of the input/output devices of both the CGS and the ADM was punched tape. Software has been developed which can be used to produce control tapes for most of the Watervliet N/C machines. This tape making process can be summarized as follows: a) an accurate drawing of the part profile is digitized on the ADM using the optical line follower/digitizing feature, b) the ADM output tape is processed on the IBM 360-44 via the CGS for the requested N/C machine, and c) the computer output is the program tape which is used to control the subject operation on the subject machine.

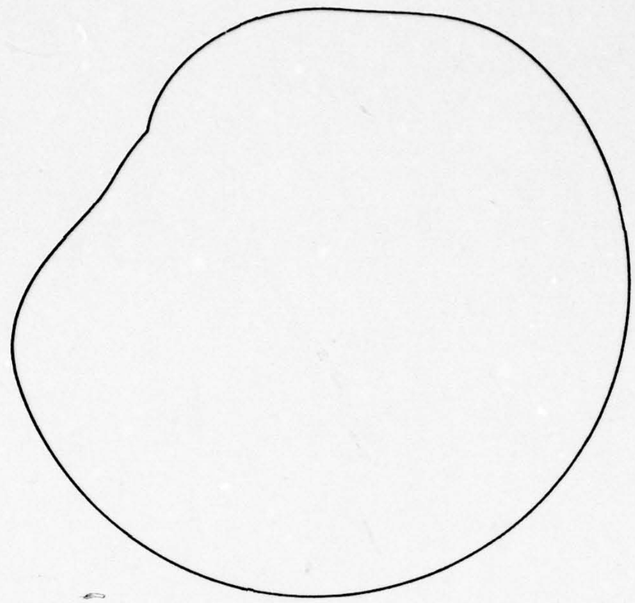

Figure 2 - General CAM Path Drawing

BENEFITS

Substantial but unquantified reductions in engineering design, programming and drafting labor, direct labor and N/C machine time have been experienced.

IMPLEMENTATION

Implementation of the foregoing ADM capabilities, as described in the summary, was completed by Watervliet Arsenal. As the need arises, new programs will be developed to minimize drafting efforts and maximize ADM utilization.

MORE INFORMATION

Additional and more detailed information may be obtained from Technical Reports WVT-TR-76042 and WVT-TR-77011 dated March 1977 or by contacting Victor H. Montuori, AV 974-5225 or Commercial (518) 266-5225.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

ELECTRONICS

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project H75 9665 titled, "Manufacturing Methods for the Production of Electronic Components Under Dynamic Stress" was completed by the US Army Electronics R&D Command in March 1979 at a cost of $735,000.

BACKGROUND

Present manual production testing of electronic components utilizes obsolete procedures which do not adequately reflect actual operating conditions, parameters, or loads.

New methods are needed for testing electronic devices and assemblies under actual operating conditions and for accomplishing the necessary adjustment or trimming. This concept is not economically feasible using present techniques due to increased testing time and necessary data reduction. The project is based on R&D sponsored by the US Navy and additional work by Singer Liberscope, Glendale, CA.

SUMMARY

The project's objective was to develop a dynamic test and correction system capable of high-speed testing and laser-trimming of electronic assemblies. Lockheed Electronics Company performed the project work and chose the amplifier and oscillator assemblies of the M732 fuze to demonstrate the technique. Parameters selected for adjustment were fuze amplifiers Height of Burst (HOB) and oscillator sensitivity. The specifications required circuit testing at rates of 3000 per hour with laser trim accuracy and/or repeatability of ± 0.05 percent.

The work was divided into four parts:

a. Tester Design - The test system utilized a computer with a Hewlett Packard (HP) 2112A Microprocessor to generate all Unit Under Test (UUT) stimulus signals, to record responses, and to calculate properties for dynamic adjustment.

The desired HOB or sensitivity was obtained by computer controlled laser trimming of the unit's thick film resistor or capacitor.

A frequency counter, D/A and A/D converters, and multiplexer were included as HP subunits, see Figure 1.

Figure 1 - Test and Correction System

b. UUT Modifications - A modified design for producing M732 fuze amplifier and oscillator assemblies was developed by substituting thick film trimmable resistors and capacitors. The modified amplifier circuit is illustrated in Figure 2.

c. System Checkout - Test hardware and software were scheduled for integration and system checkout using prototype UUTs.

d. Test and Tune - Real-time test, trim, and tune processes were to be validated by formal demonstration.

The work was not completed due to economic considerations. A careful evaluation of the potential savings to the M732 project showed that the M732 fuze was too far into production to benefit from the MMT effort.

Significant technical accomplishments included:

a. computer system hardware and 100 percent of the software necessary for fuze amplifier circuit testing were developed.

b. UUT amplifier and oscillator circuit models were built to yield information needed for trimming/tuning circuits at the required specification rate of 3000 per hour.

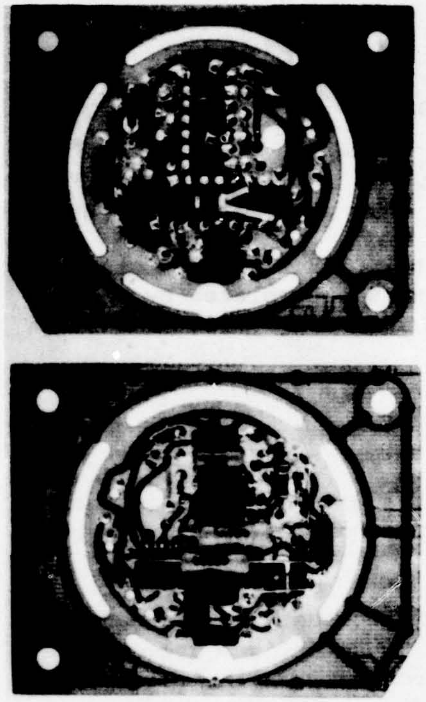

Figure 2 - ECOM Production Board

BENEFITS

The automatic circuit adjustment techniques, hardware, and software, developed are applicable to other circuits requiring measurement of DC, AC, video gain, rectifier transfer analysis, voltage threshold, and waveform analysis, etc. No cost reduction was proven but the methods established are capable of eliminating special test setups, reducing test time and improving device yields. The methods developed by this project are not unique to the M732 fuze.

IMPLEMENTATION

Techniques developed by Lockheed are currently being used on the M734 fuze production. Copies of the final report have been distributed per contact requirements and also sent to the M734 hybrid circuit subcontractor.

MORE INFORMATION

Additional information may be obtained from Mr. Edward W. Burke, Harry Diamond Labs, Adelphi, MD, AV 290-3077 or Commercial (201) 394-3077. The contract was DAAB07-76-C-0032.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project R77 3168 titled, "Methods for Manufacturing Heat Pipes for Circuit Cards" was completed by the US Army Missile Research and Development Command in April 1979 at a cost of $172,000.

BACKGROUND

The complexity of new electronic systems has given rise to increased component packaging densities on printed circuit boards (PCBs) with resultant higher cooling requirements.

The integrated heat pipe is an inclosed shell housing a wick arrangement and a specific amount of working fluid. These devices are capable of resolving many electronics packaging problems through their inherent characteristics of extremely high thermal conductance, space savings, and light weight, but have only been demonstrated as custom-made units.

Production techniques were required to improve yield, assure reliability, and reduce costs.

SUMMARY

Highes Aircraft Co. established low cost volume production techniques for fabricating integrated heat pipes for PCBs. The manufacturing technology was demonstrated by constructing the ten-bar heat pipe shown in Figure 1. This representative circuit card is a five inch by six inch, 50 watt, 50 dual-in-line package (DIP) type.

The manufacturing techniques used are applicable to an almost unlimited number of other heat pipe configurations. Size of the component mounting bars and condenser section is dependent upon heat pipe shell material, shell forming and joining techniques, as well as thermal and fluid flow parameters. Figure 2 illustrates a heat pipe circuit card in a card cage.

Extensive analysis and testing were performed to determine optimum heat pipe materials and manufacturing methods.

Brass (copper CDA 260) was selected for the heat pipe shell, sintered stainless steel fiber for the wick, and acetone for the fill fluid. Metal stamping was used to form the brass heat pipe shell, and hydrogen furnace brazing for shell sealing and wick bonding.

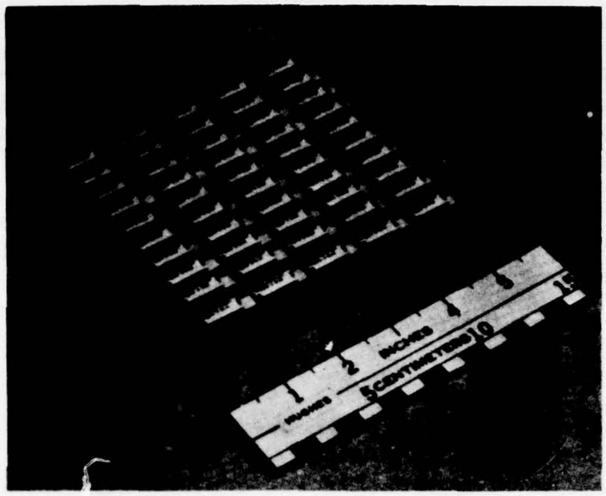

Figure 1 - Hughes-developed heat pipe card with DIPs installed

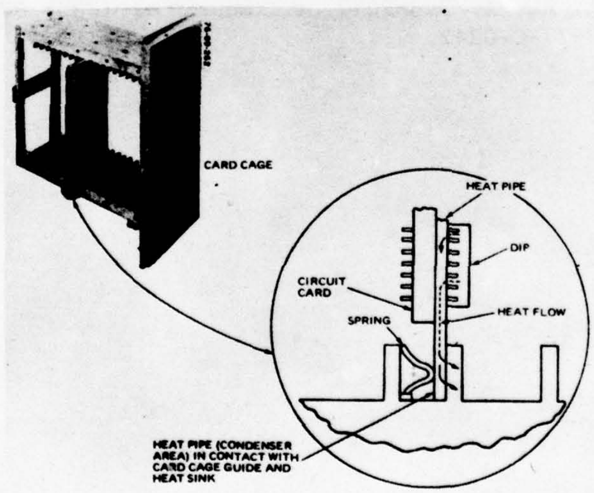

Figure 2 - Representative Heat Pipe Circuit Card Application

A multiple fill station comprised of vacuum pumps and three way valves was utilized for evacuation and fill. Pinch off included both cold and hot weld processes.

Final test utilized a thermocouple temperature measurement method with a response time of two seconds and a readout accuracy of 0.1°C.

BENEFITS

As a result of the manufacturing processes established by this project, a contractor will be capable of evacuating, filling, and sealing heat pipes at a production rate of 50 per hour. Heat pipe cost was reduced from $400 each to approximately $48 each based on 500 units.

Advantages provided by integrated heat pipes include higher power density capability, optimized component layout, spreader plate elimination, and reliability enhancement.

IMPLEMENTATION

Copies of the final report have been distributed to various organizations as specified by the contract. Production methods for heat pipes have been demonstrated and requirements for a pilot line have been compiled and are available for implementation.

MORE INFORMATION

Additional information may be obtained from Mr. Willard Hoft, MICOM, Redstone Arsenal, AL, AV 746-2077 or Commercial (205) 876-2077. The contract was DAAK40-77-C-0242.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT - 302)

Manufacturing Methods and Technology project 272 9366 titled, "High Power Traveling Wave Tubes (TW) with Improved Heat Tolerance" was completed by the US Army Electronics R&D Command in May 1977 at a cost of $513,811.

BACKGROUND

High output power requirements and size limitations imposed on tubes used in the final stage of transmitters cause heat buildup in the tubes resulting in shortened tube life. This is especially true of TWTs whose efficiency is inherently low; most of the input power is given off as heat. Present forced air and liquid cooling systems are inadequate. Vapor phase cooling appears to have potential for the high power 10 kilowatt continuous wave TWTs. Medium power 100 watt continuous wave TWTs suffer premature failure because the characteristics of the internal magnets change at elevated temperature.

SUMMARY

This project was concerned with two tubes - one, a medium power 100 watt continuous wave TWT and the other, a high power 10 kilowatt continuous wave TWT.

Teledyne MEC, a firm with experience with samarium cobalt magnets which withstand high temperature without degradation, worked on the medium power TWT. Methods and procedures in general use at Teledyne MEC were employed to determine preferred manufacturing methods. New procedures were developed for preparing and stabilizing the samarium cobalt magnets. Only two special tools were required: a cathode alignment fixture and a helix insertion fixture. They were built and used on first article and production tubes with good results. Eight tubes were produced in a pilot run with a yield of 67%. The firm predicted a yield of 85% for a larger production run of 50 units per month. This tube is shown in Figure 1.

Hughes Aircraft Company Electron Dynamics Division worked on the high power TWT. They designed a 10KW continuous wave TWT with a 50% minimum total system efficiency, ruggedized to withstand mechanical and environmental conditions. This order of efficiency over the 13% fractional bandwidth was difficult to achieve and not previously attained with a coupled-cavity TWT. Vapor phase cooling was incorporated in the design, see Figure 2.

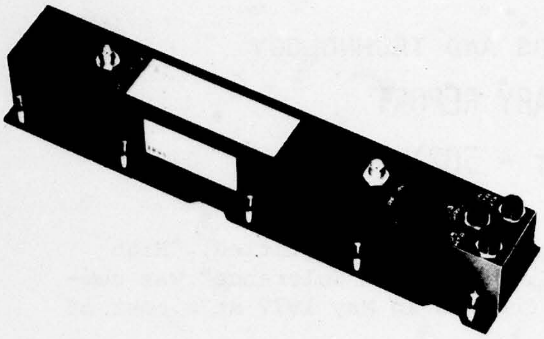

Figure 1 - 100 Watt Traveling Wave Tube.

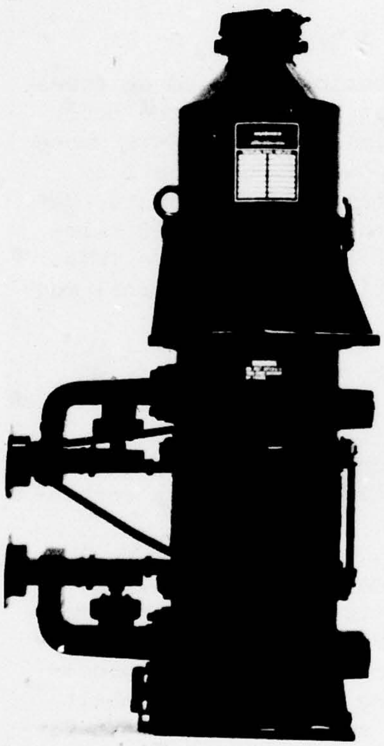

Figure 2 - 10 Kilowatt Traveling Wave Tube.

Hughes fabricated special tooling to prevent warpage and undue stressing of the pole piece blank and finished assembly during each machining operation. A sequential scheme was worked out allowing assembly, machining, and brazing to be performed as a function of the cold match characteristic of the pole piece and its accompanying components.

Hughes utilized heliarc welding, RF induction brazing, and conventional brazing in manufacturing this tube. Some assemblies were self-jigging for the brazing operation so that no special fixtures were required. After brazing, vacuum integrity of assemblies was checked. Yields of the various assemblies in the tube were from 90 to 98%.

BENEFITS

A 100 watt continuous wave TWT with longer life and greater gain was production engineered; it is identified as type 5844-A. A 10,000 watt continuous wave TWT with vapor phase cooling and improved design was also production engineered. It has an unusually high 50% minimum total system efficiency over a 13% fractional bandwidth; the tube is identified as type 636H.

IMPLEMENTATION

Reports from both firms were widely distributed throughout Government and industry. Teledyne MEC now incorporates samarium cobalt magnets in their type MTZ-5002 and MTI-5001 tubes. These tubes are used in jamming systems.

The Hughes' vapor phase cooling technology was transferred to Varian through reports and contact with ERADCOM project engineers. Varian incorporated vapor phase cooling in their 10 kilowatt continuous wave klystron type VA908R. This tube is used in the AN/TRC-170 Communications Set.

MORE INFORMATION

Additional details may be obtained from Mr. Gunther Wurthmann, project engineer at US Army Electronics Technology and Devices Laboratory, AV 996-5794 or Commercial (201) 544-5794, Ft. Monmouth, NJ 07703, ATTN: DELET-BM.

Summary Report was prepared by Ed Zajakala, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 274 9523 titled, "Manufacturing Methods for the Production of Infrared Filters" was completed by the US Army Electronics Command in June 1977 at a cost of $43,552.

BACKGROUND

The infrared filter in the AN/VSS-3A Searchlight was considered visually insecure because of pinholes and other light leaks. Many users of this searchlight criticized this fault. Also, after about 300 hours of operation, the filter coating started peeling off the glass substrate rendering the filter useless.

SUMMARY

Metavac developed processes for the manufacture of infrared filters, Figure 1, for the searchlight. The process included cutting the glass tubing to size, bevelling the edges, giving the glass cylinder a special treatment on its inner surfaces, vacuum deposition of the filter coating, and fabricating, treating, and assembling the metallic parts. Careful inspection of the items followed each operation. Some of the inspections were made to detect imperfections in the glass and the surface coating. Other inspections were for light areas, pinholes, streaks and scratches in the vacuum deposited coating. Another inspection was made to test adhesion of the coating.

Figure 1 - Infrared Filter for AN/VSS-3A Searchlight.

For application of the filter coating, the glass cylinder is mounted on a rotating table in a vacuum chamber. During vacuum draw down, the glass cylinder is subjected to a glow discharge cleaning. The cylinder is then preheated and the coating materials are applied to the outside surface by thermal evaporation as the cylinder rotates. After the last layer is deposited, the cylinder is reheated to increase hardness and adhesion of the filter coating. The surface treatment increased the resistance of the glass to failure and breakage at high temperature. It also decreased ultraviolet and visible light transmission without decreasing transparency in the infrared range.

Extreme cleanliness during the filter depostion and use of fresh materials are of paramount importance for a high yield.

BENEFITS

The number of pinholes in the coating was substantially reduced. The unit price was reduced from $400 to $225 in like quantities and the production yield was increased from 40% to 60%. Filter life was increased from about 300 hours to over 800 hours.

Based on a saving of $175 per unit, unaudited savings of $332,500 were realized as a result of this project.

IMPLEMENTATION

A pilot line capable of producing infrared filters was established. Two pilot runs were made at a production rate of ten units per day. Since completion of the project, 400 filters have been produced for the Army and approximately 1500 for prime contractors making the AN/VSS-3A searchlight for the Army.

MORE INFORMATION

Additional information may be obtained from Mr. Don Merritt, project engineer, at Night Vision and Electro-Optics Laboratory, AV 354-5286 or Commercial (703) 664-5286.

Summary Report was prepared by E.F. Zajakala, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 275 9525 titled, "Hot Pressing of Piezoelectric Elements for High Voltage Transformers" was completed by the US Army Electronics R&D Command in December 1979 at a cost of $229,000.

BACKGROUND

Using piezoelectric materials for converting electrical to mechanical and then reconverting back to electrical energy was proposed approximately 50 years ago. This technology was applied to night vision goggle power supplies, but the piezoelectric transformers (PET) could not meet military low temperature or size requirements.

R&D efforts produced a new PET transformer which met the specifications for operating 18mm night vision image intensifier tubes. The design utilizes ceramic disks comprised of a modified composition lead zirconate-lead titanate (PZ-PT) material.

The purpose of this project was to improve processing techniques and establish a production capability for this device.

SUMMARY

Honeywell Inc. established the production methods and techniques for piezoelectric transformers used in operating 18mm night vision image intensifier tubes. The 18mm PET package was initially developed with two washer-shaped piezoelectric ceramic elements. During the project, it was demonstrated that a single ceramic disk with the electrode design depicted in Figure 1 could provide the necessary power outputs. This element was mounted in the package illustrated in Figure 2. The primary terminals P^+ and P^- were used for the larger split electrodes while the smaller split electrodes provided the V_{12} and V_3 secondary voltage outputs.

Processes optimized to achieve lower manufacturing costs include hot pressing the PZ-PT material into slugs, slicing the slugs into ceramic disks, semiautomatic silk screening of the disk electrodes, semiautomatic disk polarization, and injection molding for forming the thin wall disk package container.

A double action hot press die produced slugs three times the initial length, reduced hot processing labor by 60 percent, and increased sliced element yield from 90 percent to 96 percent.

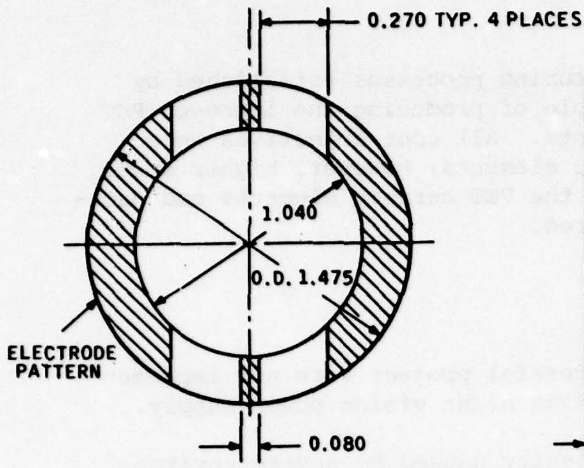

Figure 1 - 18mm Element

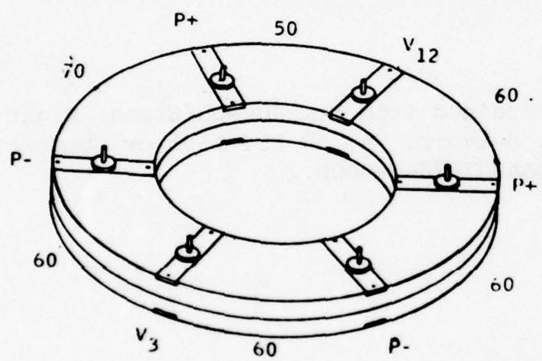

Figure 2 - 18mm Package Case

A gang saw (wafering machine) utilized a fine 600 mesh silicon carbide grit to reduce slicing cost by 75 percent and eliminate a lapping operation.

Ball bonding, thermal compression bonding, and other lead attachment methods were investigated. Best results were achieved by soldering gold ribbon directly to the silver electroded disk elements after pretinning.

A test console was designed and built to provide rapid parameter measurements on each 18mm PET. This equipment succeeded in reducing test time and costs. The console circuitry consists of a voltage-controlled oscillator which sweeps the drive amplifier through the frequency range in search for the PET resonator frequency. When a resonant point is found, the circuit dwells at the resonant frequency and parameter measurements of input current, input voltage, output voltage, and operating frequency are made by digital test instruments. These instruments have BCD outputs for eventual printer capability.

BENEFITS

As a result of the improved manufacturing processes established by this project, a contractor will be capable of producing the improved PET at a production line rate of 200 per month. All cost objectives were achieved on the individual piezoelectric elements; however, higher costs were associated with attaching leads to the PET ceramic elements and packaging was more time-consuming than desired.

IMPLEMENTATION

The results of this technically successful project were not implemented due to difficulties with the PET driven night vision power supply.

Increased power supply circuit complexity caused by severe environmental operating conditions made the piezoelectric transformer implementation economically unfeasible at this time.

MORE INFORMATION

Additional information may be obtained from Mr. Joseph Evans, Night Vision and Electro-Optics Labs, Ft. Belvoir, VA, AV 354-1551 or Commercial (703) 664-1551. The contract was DAAB07-76-C-0008.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 275 9738 titled, "Epitaxial and Metallization Processes for GaAs READ Impatt Diodes" was completed by the US Army Electronics Command in June 1977 at a cost of $503,000.

BACKGROUND

Gallium Arsenide (GaAs) Impatt diodes with high two to three watt power outputs, minimum 20% efficiencies in the nine to sixteen GHz frequency band are needed for new, low cost, lightweight, expendable Army radar systems. R&D laboratory efforts achieved the required diode specifications by using the READ doping profile which is built in during a wafer epitaxial growth process.

SUMMARY

The purpose of this MMT effort was to introduce production techniques for economically growing READ Impatt diodes outside the laboratory.

Raytheon Company at Walthan, MA established the manuacturing methods for economically producing uniform READ Impatt diodes in the X (9-11 GHz) and Ku (14-16 GHz) frequency bands. READ wafers were produced by epitaxial deposition of suitably doped GaAs layers on a highly conductive single crystal GaAs substrate. Work performed included methods for controlling layer axial and radial uniformity, Schottky photolithography and etching, Schottky barrier metallization, gold plating, and flat lapping.

The Schottky metallization barrier was created by sequentially sputtering three metals - platinum, titanium, and gold - onto the GaAs surface. Platinum constituted the Schottky barrier and titanium formed the metal diffusion barrier. Gold prevents the titanium from oxidizing and facilitates a succeeding gold plating operation.

Pulse plating was used to electroplate the gold heat sink material to the Schottky metallization and also reduce wafer edge buildup. Spray dicing which involved photolithographic masking techniques was used to separate individual diode chips from the wafer. A typical diode chip configuration is shown in Figure 1.

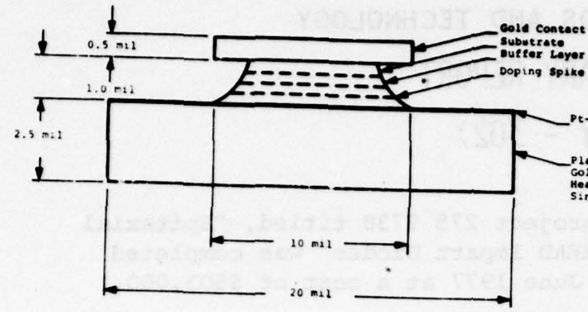

Figure 1 - READ Profile IMPATT Chip Configuration

Diode chips were assembled in the Raytheon type 16A package shown in Figure 2. The gold plated integral heat sink served as the device anode and is soldered to the package pedestal. Contact to the GaAs cathode was provided by crossed gold wires thermocompression bonded to the chip back metallization and then bonded to the flange.

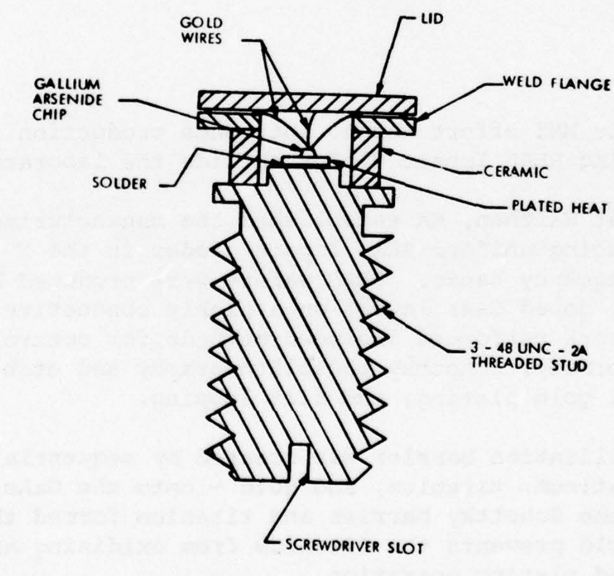

Figure 2 - Diode Cross Section of Plated Heat Sink Design

Device thermal resistance testing time was halved by adding a 25 position fixture fitted to an oven. This unit allows calibration curves to be recorded on 25 diodes simultaneously, separate from the pulsing apparatus. Noise measurements were performed on a Raytheon CNA 20 Noise Analyzer. This equipment uses a microwave discriminator and direct detection techniques which eliminate the complex operations associated with heterodyne systems.

BENEFITS

This project successfully established production techniques and increased wafer yield after the initial start up sequence from 20 percent to 50 percent.

High power X band and Ku band Impatt diodes can replace more expensive triodes and are capable of use in applications where tubes cannot be employed.

IMPLEMENTATION

Process improvements developed in this effort are being optimized for further cost reduction in follow-on MMT project 276 9738. The follow-on effort will add a computer controlled system for operating and monitoring the epitaxial growth process. It will incorporate feedback control to compensate for variations in process conditions.

MORE INFORMATION

Additional information may be obtained from Mr. James F. Kelly, US Army Electronics Command, Ft. Monmouth, NJ, AV 995-4803 or Commercial (201) 544-4871. The contract was DAAB07-75-C 0045.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 376 3147 titled, "Additive Process for Fabrication of Printed Circuit Boards" was completed by the US Army Missile Research and Development Command in June 1978 at a cost of $250,000.

BACKGROUND

Printed wiring board (PWB) technology, in use for the fabrication of military electronic equipment for several years, is based on the subtractive process wherein a resist image of the circuits is applied to a metal-clad dielectric laminate and the excess metal is etched away. A modification and improvement of this process utilizing pattern plating techniques evolved with the development of reliable photoresist systems resistant to the effects of plating chemicals. By using this technique, the reduction in circuit line widths is much less than those produced using the standard subtractive process. Therefore, current processes have been refined so that reliable, high-density PWBs can be produced in quantity with 0.010-inch lines and spaces.

However, recent trends requiring lightweight, compact electronic systems has led to increased miniaturization. Therefore, a need exists to develop the materials and processes capable of producing PWBs with 0.005-inch lines and spaces.

SUMMARY

Hughes Aircraft Company was awarded a contract to develop this process. Phase I was a developmental effort which included the assessment, selection, and qualification of materials and processes suitable for fabricating printed wiring boards using the semi-additive and ultra-thin copper-clad processes. A review of the literature and a survey of laminators revealed that the materials fell into two categories: the ultra-thin copper-clad and the unclad semi-additive type laminates; see Figure 1. Test panels were fabricated from each of the candidate material types chosen and subjected to pre-screening tests. From the results of these tests, four material types were chosen for process evaluation and optimization. Process sequences were prepared for fabricating test panels using the four candidate material types. Various tests were conducted to optimize the process for

each material type. Each process was then qualified by testing four panels of each type to the requirements of the specifications. In addition, a preliminary cost analysis of the fabrication process was performed employing one of the ultra-thin copper-clad and one of the unclad laminates.

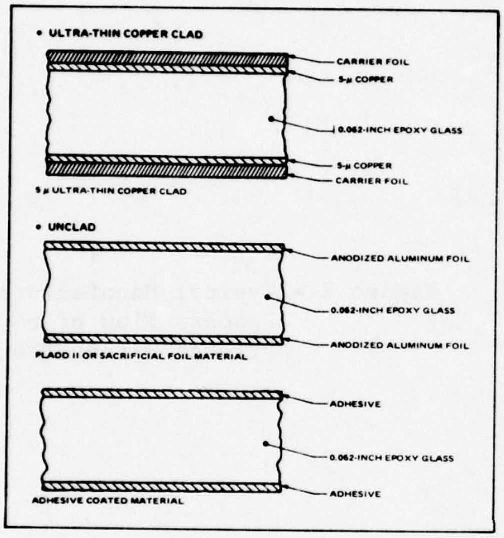

Figure 1 - Types of Epoxy Glass Laminates Evaluated.

The Phase II portion of the program was devoted to the optimization and verification of the selected PWB fabrication process. Earlier results revealed that all four material types tested passed the specification requirements. The peelable type ultra-thin copper-clad material was chosen for this task because it and the related processes can be easily implemented into the majority of PWB fabrication systems utilizing the subtractive process. The regular and modified ultra-thin copper-clad processes were optimized for the production of PWBs. Approximatley 90 PWBs were fabricated and were subjected to various tests. All of the PWBs passed the test requirement. The decision was then made to concentrate only on the regular process for ultra-thin copper-clad material for subsequent evaluation in the pilot-production line environment. This process is the one that parallels more closely the production processes presently used at Hughes-Fullerton. Verification of the processes for PWB fabrication was accomplished in a pilot production line environment. PWBs fabricated in this line were positively tested and qualified to the military requirements.

A design package of an automated production line was assembled and delivered to MIRADCOM; see Figure 2.

BENEFITS

The benefits resulting from this project include the development of a process capable of producing PWBs with 0.005 inch lines and space; and that a nine percent cost advantage can be realized with the semi-additive printed wiring board manufacture over the conventional subtractive processing.

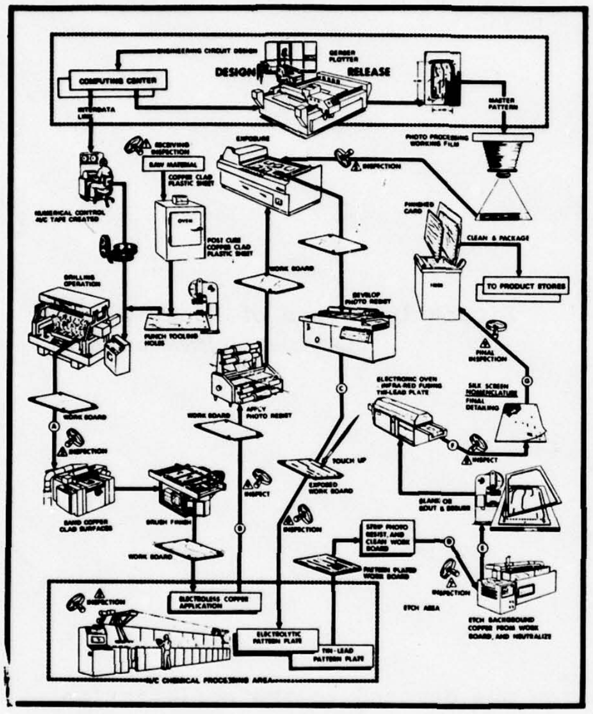

Figure 2 - Typical Manufacturing Process Flow of a Printed Wiring Board.

IMPLEMENTATION

Follow-on efforts which include further development of the process and its associated hardware are being conducted under Project No. 378 3147. This additional work must be completed before the results of the program can be implemented in a production operation.

MORE INFORMATION

Additional information may be obtained from Mr. Robert L. Brown, MIRADCOM, AV 746-3848 or Commercial (205) 876-3848.

Summary Report prepared by Robert Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 375 3157 titled, "Quantity Production Techniques for Diode Phase Shifter Elements" was completed by the US Army Missile Research and Development Command in August 1977 at a cost of $650,000.

BACKGROUND

Phase array antennas are performing increasingly dominant roles in microwave engineering but they posses the disadvantage of system complexity and high cost. These disadvantages are primarily due to the large quantities of radiator elements, phase shifters and RF power distribution networks required by each antenna, see Figure 1, Item A.

A new modular design for integrating these components was devised to minimize fabrication, assembly, and testing costs.

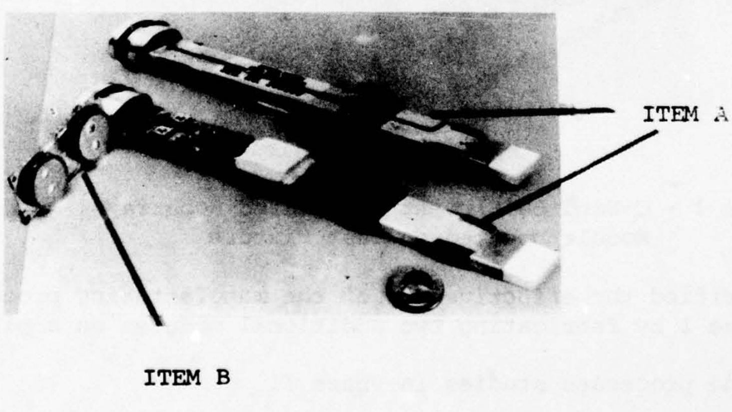

Figure 1 - Discrete Component Element Item A, Compared to Integrated Phase-Shifter Radiator Element Item B.

The selected approach developed these elements as integrated low loss microwave circuits on ceramic substrates; see Figure 1, Item B. The substrates were combined to form an integrated subarray module which was used as the basic building block for the antenna.

SUMMARY

Hughes Aircraft Company determined the materials, manufacturing processes, and techniques needed to produce low loss microwave, microstrip circuits on ceramic substrates. The project was divided into two phases.

Phase I was an investigation into optimum manufacturing methods and materials for the microstrip ceramic substrate. A subarray module consisting of 64 phase shifters and radiator elements (two radiators per substrate) was built and tested, see Figure 2.

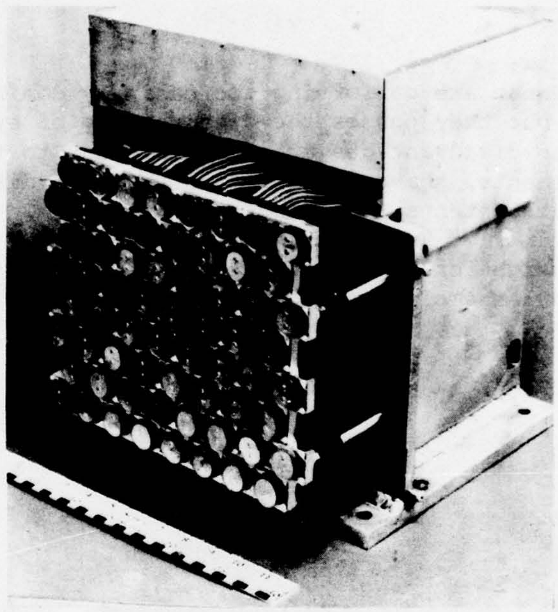

Figure 2 - C-Band 64-Element Integrated Subarray Module Mounted on Test Fixture

Phase II verified the effectiveness of the manufacturing processes selected in Phase I by fabricating two additional modules on a pilot line.

These are the processes studies in Phase I:

Prepunched alumina substrates and thick film metallization were selected as the baseline manufacturing approach. Substrate vias or holes were prepunched in the unfired alumina and proved at least five times cheaper than any other method considered. The thick film metallization process was selected since it made possible the use of thick film printed capacitors. The capacitors formed a monolithic part of the alumina substrate and required no wire or solder interconnection.

Diode chips were attached to the gold-metallized substrate by use of Indalloy 2 solder. Diode chip interconnection was made with gold strap which was welded to both the gold diode terminal and the substrate metallization. The resulting monometallic bonds precluded potential problems due to intermetallic effects. Spring clips and contacts were reflow soldered after pretinning; disc radiators were fastened with epoxy.

Following conformal coating, the subassembly was given a final DC electrical test. Final RF testing was performed at the subarray module assembly level. Electrical parameters checked included VSWR, peak power, average power, and insertion loss.

The size reduction achieved by the new substrate is illustrated in Figure 1.

BENEFITS

Minimizing the number of different type modules achieved a substantial potential for a reduction in costs and spare parts requirements. Antenna reliability was improved and assembly cost was reduced through the elimination of most interconnecting cables and connectors. The results of this project also have general application to microwave circuits such as filters, combining networks, and amplifier circuits.

IMPLEMENTATION

Project results have not been implemented and are not currently planned for implementation. Joint Army/Navy Service Contract DAAK40-77-C-0213 to fabricate Antennas for PATRIOT and AEGIS systems utilizing the diode phase shifter-radiator substrate approach was terminated by both Services due to economic considerations.

MORE INFORMATION

Additional information may be obtained from Mr. Richard A. Kotler at MICOM, Redstone Arsenal, AL, AV 746-2065 or Commercial (205) 876-2065. The contract was DAAK01-75-C-0752.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT - 302)

Manufacturing Methods and Technology project 376 3225 titled, "MMT - Production Methods for Mounting Non-Axial Lead Components" was completed by the US Army Missile R&D Command in December 1978 at a cost of $195,000.

BACKGROUND

High density electronic packaging used in present and future missile airborne guidance systems require more efficient automatic component insertion and handling techniques. Problems are associated with component leads that are long, easily bent, and numerous. Machine insertion with its high percentage of damage is often inefficient for many types of devices and costs more than manual insertion. Processes that hold component leads in alignment are needed to make machine insertion more practical.

SUMMARY

The project's objective was to reduce Printed Wiring Board (PWB) assembly cost by enhancing automated insertion method for non-axial lead electronic packages. Martin-Marietta Corp. established processes for automatic handling and insertion of non-axial electronic components in printed wiring boards. They developed a unique plastic, injection molded, locator-inserter (LOCASERT) pad and a component insertion machine to position this pad. The machine was to have the capability for mechanically feeding and inserting three major package configurations, dual-in-line (DIP) pin through hybrids, and TO-type cans. It was also required to be compatible with an automatic control system such as numerical control tape or on-line minicomputer control.

The Locasert with its tapered holes for ease of loading is adaptable to all types of non-axial lead devices and has tooling recesses at each end for positive alignment during machine pickup. Typical Locasert pads are 1/8 inch thick and are shown with components inserted in Figure 1. The system concept was based upon usage of planar PWBs that were designed or could be modified for machine insertion.

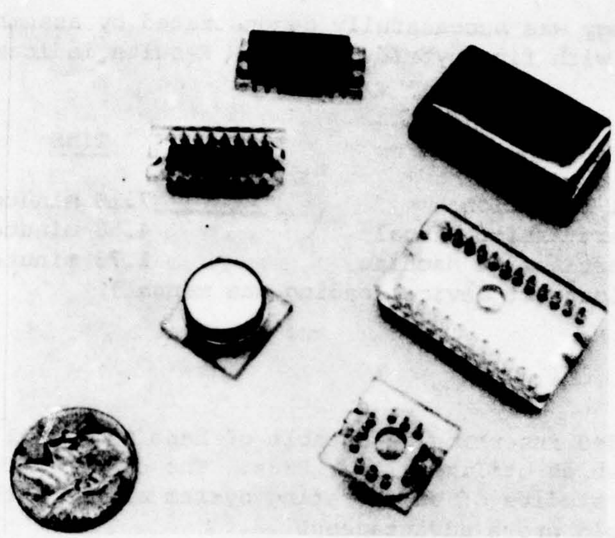

Figure 1 - Components in LOCASERTS

Component insertion occurs when PWB holes and Locasert holes are aligned. Component lead wires are inserted through both board and Locasert when the component package is bottomed onto the Locasert pad by the machine insertion head. PWB holes will be significantly larger than the Locasert holes so that problems presented by bent, deformed, or resilient lead wires are minimized. The insertion machine is shown in Figure 2.

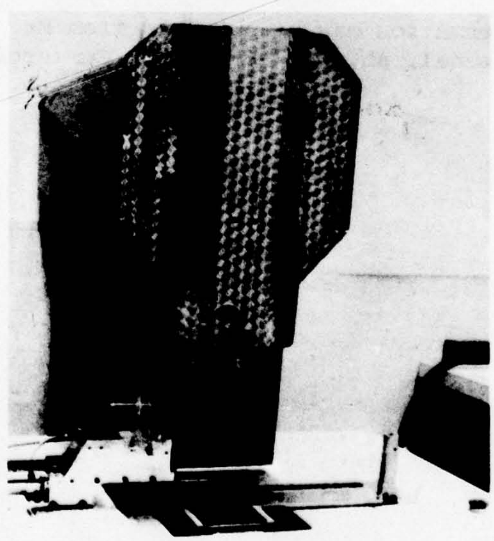

Figure 2 - Insertion Machine

The technology was successfully demonstrated by assembly of ten PWB assemblies each with five hybrid devices. Results indicated improvements as follows:

	TIME	COST
Manual Insertion	7.18 minutes	$3.52
Locasert Assist Manual	4.58 minutes	$2.25
Locasert Assist Machine	1.73 minutes	$1.73

(all Locasert device loading was manual)

BENEFITS

Locasert aided insertion is capable of benefiting all military electronic systems which utilize planar PWBs. The cost benefits of Locaserts derived by time studies of an operating system are such that adoption on a wide scale would prove advantageous.

IMPLEMENTATION

The results of this project are being optimized for further cost reduction in a follow-on MT project R80 1030. Follow-on efforts will automate the mounting and stacking of devices in magazines or sticks to eliminate hand labor. This will be followed by automatic insertion of Locaserts in PWBs and automated test.

MORE INFORMATION

Additional information may be obtained from Mr. Robert L. Brown, MICOM, Redstone Arsenal, AL, AV 746-5742 or Commercial (205) 876-5742.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 573 3051 titled, "Engineering and Fabrication of Electromechanical Inspection Test Equipment for Fuze Procurement Programs" was completed in March 1975 by the US Army Harry Diamond Laboratories at a cost of $250,000.

BACKGROUND

This project was initiated to improve, modernize and replace obsolete fuze testing in support of mortar, rocket, bomb, mine and missile fuzes currently in or scheduled for production. This test and support equipment consists of electronic, electro-mechanical and mechanical functioning mechanisms. The testing to be supported by this equipment includes: first article, engineering, reliability technical data package verification, and production testing.

SUMMARY

This effort consisted of these five tasks: (a) Fuze Acceptance tester, (b) Target Signal Simulator, (c) Low Cost Target Signal Simulator, (d) Power Supply Telemeter System, and (e) Power Supply Destructive Test Console. All of the tasks were completed and the results were as follows:

Fuze Acceptance Tester (FAT). The objective of this task was to modernize the FAT control assembly by incorporating recent advancements in analog/digital integrated circuits and solid state components. The modernization of the tester assemblies was completed and the FAT performed in accordance with the design specifications. The FAT Control assembly is a Varian 620 computer that outputs on an Anadex label printer. Also, a digital display is available for data presentation.

Target Signal Simulator (TSS) Improvement. The objective of this task was to improve the performance characteristics of the TSS to test the newer types of fuzes. This was accomplished by the development of computer software programs designed to interface with computer based test equipment.

Low Cost Target Signal Simulator. The objective of this task was to develop a low cost target signal simulator. This low cost TSS was not achieved due to switching transients and lack of dynamic range problems. The proposed solutions to these problems were costly which negated the objective of this task. As a result, the work was terminated.

Power Supply Telemeter System. The objective of this task was to design, fabricate, and test a prototype Power Supply Telemeter System. This resulted in a system that was technically acceptable but the operational performance was marginal. This system provides an alternate method of data transmission for battery testing.

Power Supply Destructive Test Console. The objective of this task was to design, fabricate, and test a Power Supply Destructive Test Console to replace the existing obsolete equipment. The test console was developed to simulate the actual initiation and electrical loading of a battery during its typical use. The console also has the capability to provide both quantitative and qualitative data output.

BENEFITS

The benefits realized by the Army from these efforts are as follows:

Fuze Acceptance Tester has been modernized with the latest circuitry and components. These new test circuits are available for high volume fuze production implementation.

Target Signal Simulator (TSS) Improvements increased the useable service life by ten years.

Power Supply Telemeter System provided an alternate method of battery test data transmission allowing for an independent evalution of voltage and noise data.

Power Supply Destructive Test Console development replaced the obsolete test equipment.

IMPLEMENTATION

Fuze Acceptance Tester System is being used to perform M732 fuze acceptance testing.

Target Signal Simulator Improvement has been installed as an intregal part of the Fuze Acceptance Test System.

Power Supply Telemeter System is being used to support the M728 and M732 production test programs.

MORE INFORMATION

More information can be obtained by contacting Mr. H.E. Brown, Jr. AV 290-3077 or Commercial (202) 282-3077.

Summary Report was prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

INSPECTION AND TEST

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project M75 6350-1621 titled, "Material Testing Technology - Measurement of Rifling Twist in Gun Tubes was completed December 1976 by the US Army Materials and Mechanics Research Center at a cost of $42,000.

BACKGROUND

Rifling in a gun tube consists of a number of equally spaced helical grooves cut in the bore of a gun. These grooves impart rotation to the projectile which is necessary to insure stability in flight. Projectiles must have a specific rotation to assure the proper performance. Current methods do not provide a direct measurement of the rifling twist produced in a gun tube. The guide slot twist in the rifling bar which guides the cutting head producing the rifling twist in the gun tube is currently measured. It is assumed that the twist produced by the rifling bar is an accurate reproduction.

SUMMARY

The objective of this effort was to develop a method and the equipment to perform a direct measurement of the rifling produced in a gun tube. The results of this effort produced a rifling twist measurement system consisting of a head assembly, Figure 1, with an angular measuring encoder mounted internally and a spring loaded drive pin on its outside diameter and a linear distance measuring device with a rotary encoder attached to an output drum. A thermal printer is interfaced to the angular and linear measuring device and holding fixture. At a prescribed position along the bore both angular and linear measurements are displayed and recorded. These measurements are used to determine whether errors are present at the prescribed locations.

BENEFITS

The primary benefit realized from this project is that the Army is fielding a more reliable, accurate and serviceable 105MM weapon system.

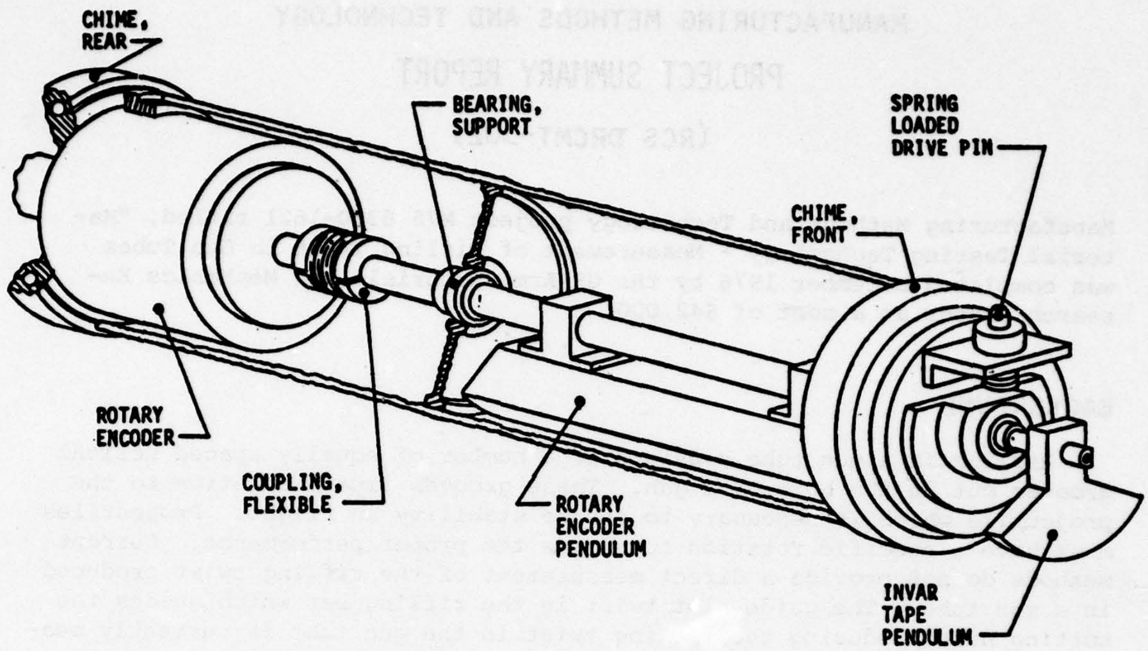

Figure 1 - Rifling Twist Measurement System

IMPLEMENTATION

The system is being used to first article inspect 105MM M68 cannon tube when a new rifling twist bar is introduced in the manufacturing process. Also, this system will be used on a sampling basis to inspect rifling twist produced by the numerically controlled rifling equipment now being purchased by Watervliet Arsenal's project REARM.

MORE INFORMATION

To obtain more information, contact the project officer, Fortune Audino, AV 974-5328 or Commercial (518) 266-5328. A final report titled, "Measurment of Rifling Twist in Gun Tubes" WVT-QA 7601 was published by Watervliet Arsenal, December 1976.

Summary Report prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 175 7096 titled, "Evaluation of NDE Techniques including Neutron Radiography (N-Ray) for Q.C. Inspection" was completed in December 1976 by the US Army Aviation Research and Development Command at a cost of $152,500.

BACKGROUND

In the manufacture of the high performance gas turbine T700 engine, it is normal practice to inspect all critical rotating parts by using conventional ultrasonic methods. The ultrasonic technique represents the best of the current NDE methods for inspecting forgings but there are questions as to its value for inspecting Hot Isostatically Pressed (HIP) components. Since all the powder passes through a #60 mesh screen during the powder processing, contaminants will be less than .010 inch in diameter, a size that is difficult to reliably inspect with ultrasonics. Another problem with ultrasonic inspection techniques is that high noise from the surface tends to hide responses from defects in the subsurface.

SUMMARY

The objective of this effort was to evaluate and compare several state-of-the-art NDE techniques with conventional ultrasonic techniques and determine their applicability for inspecting T700 HIP turbine components for non-metallic inclusions, cracks, surface defects, and porosity. The techniques evaluated were: improved ultrasonics techniques, improved fluorescent penetrant inspection, holosonics intensity mode ultrasound, holosonics acoustical holography, neutron radiography, compton scattering, and radiographic tomography.

The results of this evaluation concluded the following for detecting:

a. Non-Metallic Inclusions. The most promising state-of-the-art NDE technique was Holosonics Ultrasound equipment. This equipment demonstrated the capability to detect very small defects. Of all the NDE techniques evaluated, this is the only technique that offered any improvements over conventional ultrasonics.

b. Cracks and Surface Defects. The improved Fluorescent Penetrant Inspection (FPI) technique appeared to be superior to any other NDE technique evaluated. Of all the methods evaluated, this technique was the

only one that revealed all the known crack areas. Basically, this advanced FPI technique process consists of an acid etch followed by an ultra high sensitivity penetrant, hydrophlic remover with a non-aqueous developer.

c. Porosity. The existing Thermally Induced Porosity (TIP) test and density measuring method proved to be superior to all the methods evaluated including conventional ultrasonics and the Holosonics ultrasound equipment. One of the methods evaluated, Compton Scattering Method, had the sensitivity for accurate measurement of density but requires additional development to be introduced to a production environment.

In summary of the state-of-the-art NDE processes evaluated, Neutron radiography and radiographic tomography appear to have limited application for aircraft engines and no application with regard to rotating turbine hardware. The Acoustical Holography and Photon Scattering (Compton) methods both have potential. These techniques are both readily adaptable to fully automatic inspection of hardware, and both are cost effective. The Acoustical Holography process is in a more advanced stage of development than the photon scattering method; however, both processes require additional development prior to being introduced into a production environment.

BENEFITS

The benefit realized from this effort is the identification of two state-of-the-art inspection techniques - Acoustical Holography and Photon Scattering that have potential for inspecting T700 engine components. To date, the T700 engine manufacturer has not elected to use these inspection techniques.

IMPLEMENTATION

The Army's Armament Readiness Command is using the Photon Scattering technique to identify 105mm Comp B ammunition flaws. A final technical report, AVSCOM No. TR76-23 titled, "A Comparison of Various Non Destructive Inspection Processes Using Hot Isostatically Pressed Powder Turbine Parts, December 1976" was distributed throughout the Government and made available to Industry through Defense Documentation Center.

MORE INFORMATION

To obtain more information, contact the project officer, A.C. Piazza, AV 693-1937 or Commercial (314) 268-1937.

Summary Report was prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 274 9666 titled, "Automatic Production Testing of Imaging Devices" was completed in June 1976 by the US Army Electronic Research and Development Command at a cost of $650,000.

BACKGROUND

The second generation image intensifiers are very complex with stringent performance and production testing requirement. The first generation visual production testing methods are not acceptable for these intensifiers as they are very time consuming, subjective, and allow a large margin of error.

SUMMARY

The objective of this effort was to develop a production prototype automatic second generation image intensifier tester. This tester was intended to check eight functions and assure uniform product quality while reducing testing time. The following guidelines were established for developing this testing capability:

a. Convert subjective tests to objective tests.
b. Minimize test equipment complexity.
c. Maximize the use of existing designs and hardware.

A prototype production testing system, Automated Image Device Evaluation (AIDE), was developed and consisted of several major components that performed fast, accurate, objective tests with minimum operator participation. The measurements are performed by sophisticated computer software using a high-resolution return-beam vidicom (RBV) camera. This system, Figure 1, was developed using existing hardware and consists of the following:

Optical Bench. The bench, Figure 2, contains the electro-optical stimulus, measurement detector and mounting hardware necessary to interface with the device under test.

Electronic Station. This station provides the necessary power supplies, signal processor, photometer electronics, RBV electronics to control and operate the optical bench and to interface with the Army's low frequency Electronic Quality Assurance Test Equipment (EQUATE). The EQUATE system, using

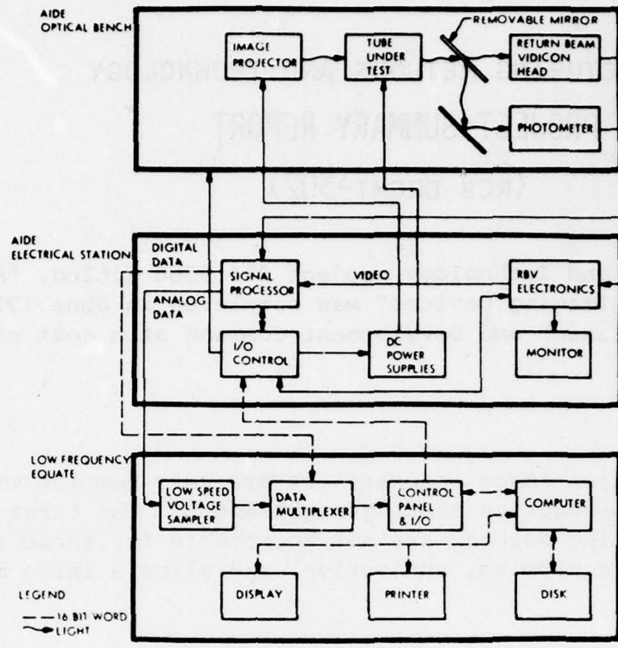

Figure 1 - AIDE System Diagram

a NOVA 800 minicomputer central panel and video terminal, provides the interface between the operator and the AIDES's Electronic Station and Optical Bench.

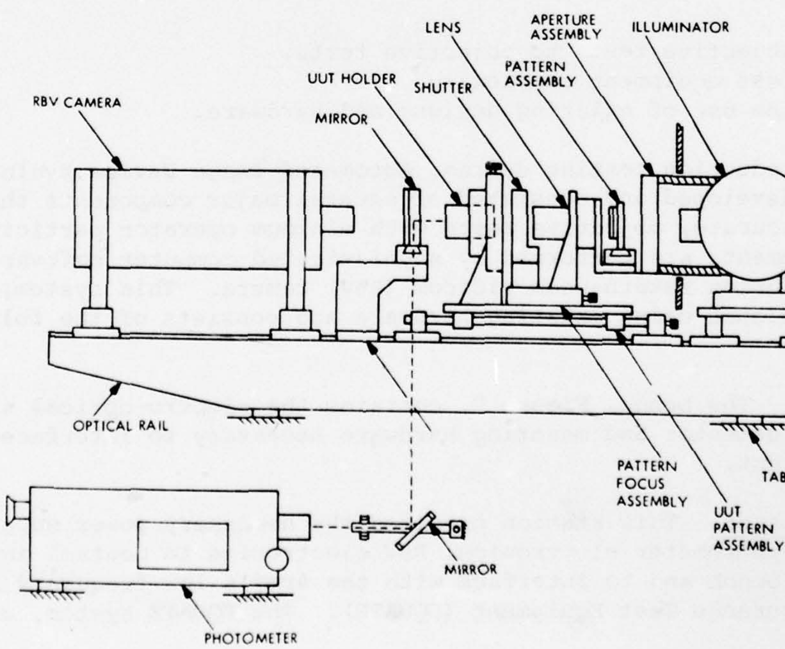

Figure 2 - Optical Bench

This effort was partially successful as a portion of the objectives set forth were accomplished. The system was intended to have the capability of performing eight functional checks: Modulation Transfer Function, Lumenance gain, equivalent background illumination, reverse polarity, blemish, fixed patter noise, signal-to-noise, and limiting resolution. Only the first four of the above functional tests were operational before the funds were depleted. Although the effort was not a total success, it demonstrated that the second generation image intensifier production testing can be automated.

BENEFITS

The results obtained from this effort demonstrated that the second generation image intensifier production testing can be automated.

IMPLEMENTATION

The results of this effort were not implemented as the project was not completed due to the lack of additional funds.

MORE INFORMATION

To obtain more information, contact the project officer, James F. Kelly, AV 995-2046 or Commercial (201) 544-2046. A final report titled, "MMT Program Automated Image Device Evaluation (AIDE) was published by RCA/Government and Commercial Systems, Automated Systems Division, Burlington, MA, December 1975.

Summary Report prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 370 3016 titled, "Inspection Acceptance Production Tool for Tubing" was completed January 1976 by the US Army Missile Command at a cost of $350,000.

BACKGROUND

The thin-walled tubing used in today's Missile systems require 100% inspection of inside and outside diameters, straightness, length, and thickness to assure reliability and flight accuracy. The currently used point-by-point manual measuring technique is time consuming and costly. It is also inaccurate and unreliable, which results in the acceptance of many defective tubes.

SUMMARY

The objective of this effort was to design, fabricate, and test a production prototype steel and aluminum thin-walled tube inspection system. State-of-the-art tube inspection techniques that were considered for this function were ultrasonics, optical comparators/shadowgraphs, roller cables, air gaging, and laser gaging. The ultrasonic inspection technique was selected based on accuracy ($\pm$0.0001 inch), ease of application, and the fact that measurements could be made externally thus eliminating the alignment problem between external and internal sensing heads. The results of the project produced automatic production prototype tube inspection equipment, Figure 1, for M200A1 rocket launcher tubes. This equipment has the capability to measure and record 1200 points on the M200A1 launch tube in a two minute period. The manual point-to-point technique required forty hours to perform the same inspection. The equipment performed satisfactorily except when used for extended periods. When used for an extended period of time, the ultrasonic transducer readings would drift, thus resulting in erroneous data.

BENEFITS

The results obtained from this effort demonstrated that an automated ultrasonic inspection technique could be used to inspect thin-walled tubing.

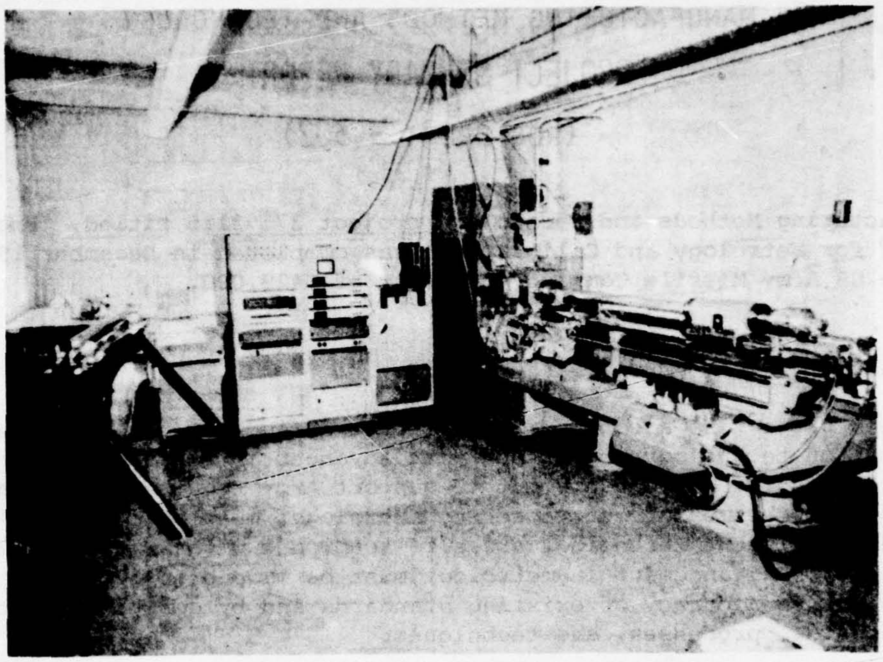

Figure 1 - Automatic Production Prototype Tube Inspection Equipment

IMPLEMENTATION

The results of this project are available for implementation and have been recommended for use for production inspection of thin-wall steel and aluminum tubing.

MORE INFORMATION

To obtain more information, contact the project officer, Mr. B. Austin, AV 746-8445 or Commercial (205) 876-8445. A final technical report RL-75-9 titled, "MMT Inspection Acceptance Production Tool for Tubing" was published by the US Army Missile Command, April 1975.

Summary Report was prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 375 3115 titled, "Engineering for Metrology and Calibration" was completed in December 1978 by the US Army Missile Command at a cost of $429,000.

BACKGROUND

This project is a continuing effort to derive new measurements and calibration technology consistent with advances in manufacturing processes, techniques and equipment to support Army requirements. The problem is that the measurement science, metrology, must be continually advanced in relevent technology areas to keep pace with Army program requirements. Advancement in metrology must be made both by increasing precision and accuracy of existing standards and by deriving new types of standards, processes, and techniques.

SUMMARY

This effort consisted of the following eight tasks:

Josephson Effect Voltage Standard
Electromagnetic Field Measurement and Analysis
Laser Interferometer Gage Block Calibrator
Pressure Transducer System
Automated Systems Standards
Automated Bolometer Calibration System
Six-Port Measuring System
IR Standard, Detector

Of these tasks, only two have been completed with the remaining six being continued. The two completed efforts are as follows:

Laser Interferometer Gage Block Calibrator. The objective of this task was to develop a gage block measuring fixtures utilizing a laser interferometer to calibrate gage blocks. The fixtures were to provide measurement capability over a zero to 20 inch range. In the development and testing stage of these fixtures, it was determined that the system repeatability was not suitable for gage block calibration. An alternate method was explored using a scaled-up National Bureau of Standard (NBS) fixture. The fixture cost for this alternate method exceeded the anticipated cost benefits and as a result, the task was terminated.

Six Port Measuring System. The objective of this task was to fabricate and evaluate a RF and microwave network calibration system based on a six port concept. This concept permits measurement of both the amplitude and phase characteristics of RF devices and requires only the use of a measuring network involving six-ports; an input, an output, and four measurement ports which are proportional to the square of the absolute magnitude of four independent phasor additions of the input and output waves. The results of this effort produced a working system. The X-band six port system, including the diode detector calibrator, was assembled and integrated into a calculator controlled system.

BENEFITS

No direct benefits were realized from the Laser Interferometer Gage Block calibration effort. Future application of the Six Port Measuring System for single and dual systems is anticipated.

IMPLEMENTATION

The Six Port Measuring System is planned to be implemented as a National Standard at the National Bureau of Standards. Also, this system is planned to be used as a primary standard at the Army's Calibration Center located at the US Army Missile Command, Huntsville, Alabama.

MORE INFORMATION

To obtain more information, contact the project officer, F.B. Seeley, AV 746-5638 or Commercial (205) 876-5638. A final Technical Report AMCC-MM-78-14 titled, "Final Technical Report for Manufacturing Methods and Technology project 375 3115 Engineering for Metrology Calibration" was published by the US Army Missile Command, Nov 1978.

Summary Report was prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT - 302)

Manufacturing Methods and Technology project 376 3115 titled, "Engineering for Metrology and Calibration" was completed in September 1979 by the US Army Missile Command at a cost of $557,000.

BACKGROUND

This project is a continuing effort to derive new measurements and calibration technology consistent with advances in manufacturing processes, techniques, and equipment to support Army requirements. The problem is that measurement science or metrology must be continually advanced in relevent technology areas to keep pace with Army programs. Advancement in metrology must be made both by increasing precision and accuracy of existing standards, processes, and techniques.

SUMMARY

This effort consisted of the following eight tasks:

- Josephson Effect Voltage Standard
- Electromagnetic Interference
- Variable Omni-Range (VOR) Navigation
- Electro-Optical and Laser System Standards
- Automated Systems Standards
- Automated Bolometer Calibration System
- Electromagnetic Field Measurement and Analysis
- Modular Equipment Configuration for Calibration and Analysis (MECCA)

Of these tasks, three were completed with the remaining being continued on project 377 3115. The three completed efforts are as follows:

Electromagnetic Field Measurement and Analysis. The objective of this task was to establish a calibration capability for Electromagnetic Interference (EMI) re.eivers having both linear and non-linear instantaneous bandwidths from 1 KHZ to 4 GHZ and RF center frequencies from 1 MHZ to 16 GHZ. Eighteen (18) antenna combinations were tested including a 280 cm, 90 cm, and 7.5 cm metal monopoles and 7.5 cm thin film resistive monopole. Simple metal triangle section horns with lengths of]5 to 36 cm and 45 degree apex angles were tested. Also, a fifteen (15) cm horn made of thin film resistive material was tested. As a result

of these tests, it was concluded that the two TEM horns and two Balum sources were best suited for use as the EMI standard. The 36 cm simple horn was selected for field calibration.

Automated Bolometer Calibration System. The objective of this effort was to develop a Bolometer and Bolometer-Coupler combinations calibration interface computer software program for use with this Six-Port Measuring System. This calibration computer software program was developed by the National Bureau of Standards and delivered to the Army. The Army Metrology and Calibration Center carefully evaluated the software program and concluded that this technique was not cost effective.

Electromagnetic Interference (EMI). The objective of this task was to establish the EMI characteristic requirements for the Army Area Calibration Teams and Calibration Laboratories. These teams and laboratories are required to operate in areas where they are subjected to serve field EMI. The EMI effects on calibration instrumentation was unknown which prompted the conduct of this study. The study results established EMI operating techniques and procedures in addition to EMI specifications for future calibration equipment procurements.

BENEFITS

The benefits realized by the Army from these efforts are as follows:

Electromagnetic Field Measurement and Analysis - an EMI receiver calibration standard was developed for laboratory and field use.

Automated Bolometer Calibration System - This system was developed and evaluated. It was concluded that this system was not economically feasible.

Electromagnetic Interference - EMI operating techniques and procedures were developed for the Army Area Calibration teams and laboratories. Also, an EMI procurement specification for future calibration equipment buys was established.

IMPLEMENTATION

Electromagnetic Field Measurement and Analysis - The EMI receiver calibration standards, TEM horns, and Balum sources are being used by the Army Calibration Center to calibrate EMI receivers. Also, the 36cm simple horn antenna is being used in the field as a calibration standard.

Electromagnetic Interference - The EMI operating techniques and procedures developed by this task are currently being used by the Army Area Calibration teams and laboratories.

MORE INFORMATION

To obtain more information contact the project officer, F.B. Seeley, AV 746-5638 or Commercial (205) 876-5638. A final Technical Report AMCC-MM-79-5 titled, "Final Technical Report for Manufacturing Methods and Technology project 376 3115 Engineering for Metrology and Calibration" was published by the US Army Missile Command, July 1979.

Summary Report was prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT - 302)

Manufacturing Methods and Technology project 373 4177 and 374 4177 titled "Development of Calibration Measurement Techniques and Equipment (CAM) was completed in August 1975 by the US Army Missile Command at a cost of $374,000.

BACKGROUND

The current Picatinny Arsenal Electronic inventory consists of 4000 items of test, measurement and diagnostic equipment (TMDE) including the Nuclear Weapons Adaptation Kit's (NWAK) TMDE and support equipment. The calibration requirements for this equipment far exceeds the Picatinny Arsenal calibration capabilities. This equipment required 12-16 thousand calibrations annually. The current Picatinny Arsenal calibration center has the capability to perform approximately 5000 calibrations annually. As a result of this short fall, this project was initiated to alleviate the NWAK's TMDE and support equipment calibration requirements.

SUMMARY

The objective of this effort was to design, fabricate, test and evaluate a NWAK Automated (Computer Aided) prototype calibration system. The results of this effort produced a NWAK Automated calibration system, Hewlitt-Packard (HP) 9213C. This computer-aided calibration system has the capability to be programmed to provide stimulus and diagnostics and to record and store calibration data for the NWAK's TMDE and support equipment. The measurement capability of this system includes DC through 1 GHz voltage and to 18 GHz for frequency and power. DC and low frequency stimulus capability extends to 4000v and to 50a. Audio and RF stimulus capability extends to 110 MHz. The system includes a 16K word digital computer which, under program control, automates the electronic measuring, stimulus, and switching devices in the system. The system software is built around the features of a Test Oriented Disc System (TODS-B) which provides for multi-language programming capability with emphasis on the use of HP BASIC. Computer peripherals include a disc drive unit with replaceable disc cartridges, a graphic display terminal with hard copy output, paper tape punch, and paper tape reader.

The computer programs are written in ATS-BASIC language for the HP 9213C systems to calibrate 179 different meters, signal generators, and

oscilloscope mainframe and plug-ins. The programmed procedures include both performance tests and explicit adjustment instruction to accomplish TMDE calibration.

BENEFITS

The benefits realized by the Army from this effort included 20% greater productivity through improved calibration times, decreased turn-around time, increased operational uniformity, better diagnositc information for the TMDE being calibrated and repaired, better utilization of calibration technicians skills, reduction in training programs, and provides more reliable maintenance management data for TMDE.

IMPLEMENTATION

This automated calibration system was initially installed at the Picatinny Arsenal Calibration Center. This system now resides at the White Sands Missile Range (WSMR). Two other systems are in use, one at the US Army Metrology and Calibration Center, Redstone Arsenal, and a second system at the WSMR.

MORE INFORMATION

To obtain more information contact the project officer, Mr. K. Magnant, AV 746-1301 or Commercial (205) 876-1301.

Summary Report was prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 576 3095 titled, "Mortar and Artillery Ballistic Simulation for Fuze Testing" was completed in March 1979 by US Army's Harry Diamond Laboratories at a cost of $221,000.

BACKGROUND

Many of the expensive Mortar and Artillery Ballistic Fuze Field Testing requirements could be reduced 50% or 200 firings per lot by using Ballistic fuze simulation techniques for dynamically evaluating power supplies. Also, the establishment of the Ballistic fuze simulation capability would minimize delays caused by adverse weather conditions and scheduling problems at proving ground test ranges.

SUMMARY

The object of this effort was to design, fabricate, test and evaluate a High Spin Table Top Artillery Simulator for dynamic testing PS 115 power supplies, Figure 1.

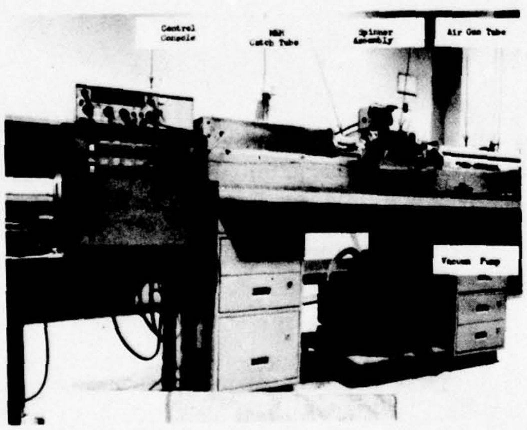

Figure 1 - High Spin Artillery Simulator (2").

The results of this effort produced a prototype simulator that has the capability to subject the PS 115 power supplies to 4000 to 5000 g's. The setback force is accompanied by angular acceleration and centrifugal forces which activates the power supply and sustains its operation for a period in excess of ten minutes. The simulation takes place in a rotating catch tube that is driven at speeds up to 18,000 rpm.

The simulator equipment is semi-automatic and provides a readout system for monitoring the power supply output voltage. The simulator is designed to test forty power supplies per hour. The simulator is self contained and operates on power supplies generally available in commercial production facilities.

BENEFITS

The benefits realized by the Army from this project are as follows:

a. The simulator provides a more reliable method for activating and monitoring the PS 115 power supply at the production site which reduces the field testing requirement by 50%.

b. This simulator had been used to test PS 115 power supplies. The estimated cost of conducting these tests on a firing range would have been $900,000. The total testing costs including the MMT project cost of $221,000 was $228,000. The use of the simulator to test these PS 115 power supplies resulted in an estimated cost savings of $672,000 or a Savings Investment Ratio of 3.94.

IMPLEMENTATION

Two production PS 115 power supply simulators have been manufactured and will be made available to the power supply manufacturers - Acudyne, Janesville, Wisconsin, and Union Carbide, Bennington, Vermont by December 30, 1979.

MORE INFORMATION

Additional information concerning this project may be obtained from H. D. Curchack, US Army Harry Diamond Laboratories, 2800 Powder Mill Road, ATTN: DELHD-I-RTT, Adelphi, MD 20783, AV 290-2804 or Commercial (202) 394-2804.

Summary Report was prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 574 6310 titled, "Advance Fuze Test Equipment and Establishment of Refined Measurement Techniques" was completed September 1976 by the US Army Armament Research and Development Command at a cost of $120,000.

BACKGROUND

The quality and reliability of fuzes depends on the testing methods used during their manufacture. A review of MIL-STD-331 revealed that certain test methods needed improvements. The Dust Test and Fungus Tests were outmoded. In the Salt Fog Test, the salt concentration was too high and unrealistic. The requirements in the Waterproofness test were found to be inadequate for hermetically sealed fuzes. The operability testing requirements of the Five Foot Drop Test and the Transportation Vibration Test were not adequate. In the Jolt Test and Jumble Test, the test equipment was outmoded. There was no uniform technique for monitoring the Jolt Test shock environment. Also, a system did not exist which accurately confirmed projectile impact angles in the Five Foot Drop and Forty Foot Drop tests.

SUMMARY

The objective of this effort was to improve fuze testing methods by developing new and modifying existing tests and test equipment. The results of the total effort produced revisions to the following eight MIL-STD-331 tests: Salt Fog Test #107, Dust Test #116, Waterproofness Test #108, Fungus Resistance Test #110, Jolt Test #101, Jumble Test #102, Transportation Vibration Test #104, and Five Foot Drop Test #111.

This particular year of the effort produced revised test methods for Jolt Test #101 and Jumble Test #102. Also, certain longevity improvements were made to the Jumble and Jolt test equipment. A Jumble test equipment wear test was performed and it was determined that polyurethane and polyethylene materials produced similar shock environments as the maple wood Jumble box and lasted considerably longer. As a result, the synthetic materials were substituted for the maple wood. A similar wear test was conducted on Jolt test equipment. It was concluded that a nylon arm and polyurethane pad did not significantly change the Jolt shock environment and was more durable. This resulted in a nylon and polyurethane material substitution.

Also, major procedural changes were made concerning the number of arms that should be used to perform the Jolt test. It was determined that a minimum of four arms should be used and that dummy fuzes should not be used to load up the extra arms since the shock is independent of the number of active arms.

BENEFITS

The Army benefits from this effort included a more realistic and repeatable fuze testing. This was accomplished by improved testing techniques that are more reliable and less expensive.

IMPLEMENTATION

A facilities project 575 6310 (MOD) implemented the equipment modification requirements resulting from this effort. These modifications were made at five government facilities and three contractors plants. Also, MIL-STD-331 was revised to reflect the results of this effort.

MORE INFORMATION

To obtain more information, contact Mr. Reap, AV 880-3790 or Commercial (201) 324-3790. A final report titled, "Improvements to Fuze Test Methods and Equipment and Development of New Monitoring Techniques" (for MIL-STD-331), FA-TR-75077 was published by the US Army Armament Research and Development Command, October 1975.

Summary Report was prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 576 6625 titled, "Establishment of an Automated Assembly and Inspection Line for Beehive Fuze Movements" was completed in July 1978 by the US Army Armament Research and Development Command at a cost of $693,000.

BACKGROUND

The Army's decision to establish an M571 Beehive Fuze Movement Automated Assembly and Inspection line (AAI) to support the projected mobilization rates prompted this MMT effort. The M571 fuze movement was similar to the M564 and M565 fuze movements which were being phased out of production. In a prior effort, an AAI line had been designed for the M564 and M565 fuzes which required 25 machines. However, only five of these 25 machines were fabricated. Because of the similarity of the fuze movements, it was determined that it would be beneficial to modify the design and machines originally intended for the M564 and M565 fuzes movements to accommodate the production of the M571 fuze movements.

SUMMARY

The objectives of this effort were: a) to modify the design of the existing M564 and M565 AAI line to reflect the M571 Beehive Fuze Movement requirements and b) to update the related equipment Technical Data Package. This effort produced a modified AAI line design and equipment specifications for the M571 Beehive Fuze Movement. This line consisted of 36 machines. Included in the AAI line design are 26 in-process inspections which are to be performed at sixteen equipment stations on nine different machines. These inspections include: Torque, Spin, Centrifugal, Firing Pin, and Load Setback tests. Also, this Beehive Fuze AAI line design concept would allow the M564, M565, and M571 fuze movements to be produced concurrently by adding ten machines and performing minor modifications to the existing machines.

BENEFITS

The benefit realized by the Army from this effort is the partial recovery of the initial AAI design investment. This was done by modifying the original twenty-five machine design to permit production of the AAI of M571 fuze movement.

IMPLEMENTATION

The five M564 and M565 AAI units are currently being modified by Facilities project 578 6652. Two of the units have been accepted by the Army. The remaining units are expected to be available in December 1979. However, since the inception of this MMT project, the M571 fuze movement has been phased out of production, thus eliminating the benefits of the implementation.

MORE INFORMATION

Additional information concerning this project may be obtained from Mr. David T. Kimm, AV 880-3265 or Commercial (201) 328-3265.

Summary Report prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 673 7182 titled, "Holographic Interferometry System for Measuring Large Aperature Optics and Aspherics" was completed July 1975 by the US Army Armament Research and Development Command at a cost of $107,000.

BACKGROUND

The current Large Spherical and Aspherical Optical Surface inspection technique for measuring curvature and irregularity requires numerous sets of test glass reference masters of extremely high quality which are fragile and expensive to manufacture. The physical contact required between the test reference glass and surface being tested results in surface wear and damage to both the reference masters and the optics being tested. Also, this technique is very labor intensive requiring numerous removals and repositionings of the optics in the test fixtures.

SUMMARY

The objective of this effort was to design, fabricate, and test prototype precision measurement equipment using a Holographic Interferometry System to supply a wavefront of a desired shape for comparison of large diameter and aspheric optics. The results of this effort produced prototype optical Holographic test equipment. The optics to be tested are placed in contact with the test equipment as depicted in Figure 1. When the laser is turned on the hologram, it produces a beam which strikes the surface so as to produce a collimated beam upon reflection. The reflected beam propagates back through the hologram to interfere with the comparison beam. This is reflected on to the screen where the inspector performs a visual comparison for the acceptance test.

BENEFITS

The potential benefits to be realized by the Army by implementing the results of this project are as follows:

a. This system would substantially reduce the inspection manhours.

b. Eliminate the requirement for special measuring equipment and holding fixtures.

c. Eliminate surface wear and damage to the optics under test.

d. Eliminate the large and expensive test glass inventory.

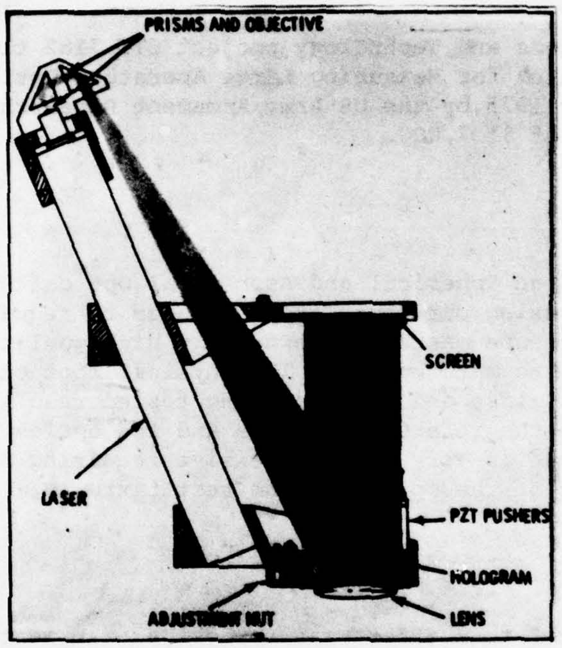

Figure 1 - Optical Holographic Test Equipment

IMPLEMENTATION

The results of this effort are in the process of being implemented at the Army Armament Research and Development Command's Optical Fabrication shop located at Dover, New Jersey and is expected to be operational by January 1980.

MORE INFORMATION

Additional information may be obtained by contacting Mr. N. Scott, AV 880-6430 or Commercial (201) 328-6430.

Summary Report was prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 772 3501 titled, "Develop Technology to Nondestructively Measure Residual Stresses in Large Complex Steel Weldment via the Mossbauer Effect" was completed in Aug 1975 by the US Army Mobility Equipment Research and Development Command at a cost of $161,000.

BACKGROUND

During the fabrication of large complex steel weldments such as the tongue and boom components for Armored Bridge Launcher Vehicle, residual stresses are introduced which decreases the load capacity of these components. Currently, there is not an acceptable production method available to nondestructively measure the magnitude of these stresses.

SUMMARY

The objective of this MMT effort was to develop production equipment and procedures to nondestructively measure residual stresses by employing the Mossbauer principle. The Mossbauer principle measures stress in a fundamental way. The density of the electronic wave function at the ^{57}Fe nucleus affects measureably the energy at which the Mossbauer resonance occurs. Compression increases the density and causes the resonance to shift to lower energy. The converse is true with tension. The Mossbauer measurement does not indicate whether the stress is uniaxial, biaxial, or hydrastatic. The measurement is basically of an "equivalent hydrostatic stress" since it measures ultimately the electron wave function density of the iron nuclei and the extent to which this is affected by the stress.

The residual stress measuring equipment was built, installed, and tested, Figure 1. The equipment demonstrated that an acceptable level of precision could be achieved. The precision level was +500KSI. This exceeds that of any other technique for measuring surface stresses. The stress measurement is an average level over the area covered at a depth of approximatley 100 nanometers.

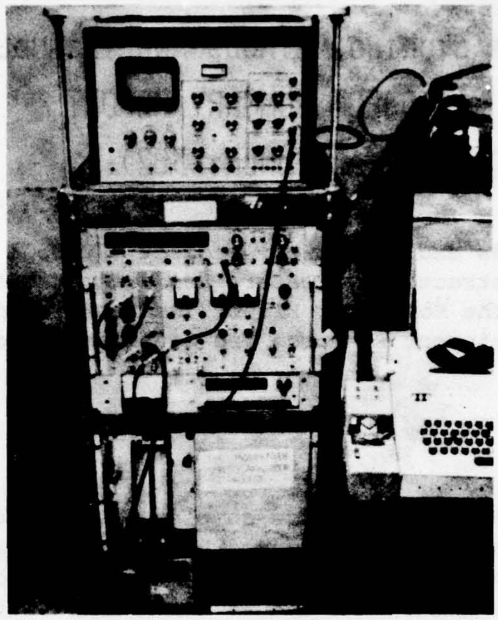

Figure 1 - Complete stress analyzer equipment.

BENEFITS

The primary benefit realized by the Army from this project is the fielding of Ribbion bridges with greater reliability and service life. These bridges will not have components with unacceptable residual stress levels that lead to premature failures.

IMPLEMENTATION

This residual stress measuring system is being used by the MERADCOM Material Research Laboratory Model - Fabrication Facility - to determine stress levels of the steel components used in the production of the Army's Ribbion bridge.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. Emil York, AV 354-5820 or Commercial (703) 664-5126. A final report titled, "Surface Stress Measurement with the Mossbauer Effect" was published by Austing Science Association, Inc., Austin, TX 78746, Contract No. DAAK02-71-C-0110.

Summary Report prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 774 3567 titled, "Test Equipment, AN/PRS-7 Mine Detector" was completed by the US Army Mobility Equipment Research and Development Command in December 1976 at a cost of $180,000.

BACKGROUND

The current production acceptance test for AN/PRS-7 mine detector uses a 12 x 6 x 2 ft. marble block weighing twelve tons. Due to the size of the marble block, the production acceptance testing is conducted at a centralized test site which is very time consuming and costly.

SUMMARY

The objective of this effort was to design, develop, and fabricate a light weight portable test simulator of reasonable size and weight. The results of this effort produced a 250 pound, 4' x 4' x 2' production acceptance testing device with a dissapative low density testing medium. The test medium, rotatable target cylinder, and the adjustable target response characteristics were considered to be major achievements in producing this tester. This portable testing equipment was used to test four AN/PRS-7 mine detectors and the results were compared to the test results obtained from the "marble block testers" for the same mine detectors. The only reading that did not meet MIL-D-52634A(MF) was the low point. This out-of-specification condition was attributed to the presence of a large metallic object located near the testing area.

BENEFITS

The benefits realized by the Army from this effort was the capability to decentralize the AN/PRS-7 mine detector production acceptance and in-service testing. This decentralized testing will result in reduced testing time and cost.

IMPLEMENTATION

As a result of this effort, two AN/PRS-7 mine Detector Testers are being used by the Cubic Corporation of San Diego, CA to conduct Engineering tests for the product Improved AN/PRS-7 mine detector. These mine detector testers will be used for production acceptance testing of the product improved mine detector.

MORE INFORMATION

Additional information on this effort is available from P. M. Pecori, MERADCOM, Ft. Belvoir, VA, AV 354-4498 or Commercial (703) 664-4498. Reference Technical Report "ARTECH COPR" Report No. J7344-FR titled, "Design and Construction of Lightweight Test Simulators for AN/PRS-7 Mine Detectors" dated April 16, 1975.

Summary Report was prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

METALS

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project M75 7590 titled, "MMT Establishment of a Production Base for the Watts Casting Process" was completed by the US Army Materials and Mechanics Research Center in February 1978 at a cost of $100,000.

BACKGROUND

At the outset of this project, a raw material procurement problem existed relating to gun barrels and similar forged products. The problem was that there was no economical means of producing hollow preforms of acceptable quality.

SUMMARY

The objectives of this project were to establish a process that would produce hollow preforms of satisfactory, quality levels at a reduced cost, and to design a casting machine to produce hollow gun barrel forging blanks.

Initial tests of material cast in solid form by Technical Instruments Corporation using their Watts Horizontal Continuous Casting Process revealed that the quality produced was appreciably superior to either the ingot-poured or the conventional continuously cast product. Thus the material cast by the Watts process appeared to fulfill all of the quality requirements. Technicon then proceeded to design a machine that could produce hollow gun barrel forging blanks under the auspices of AMMRC.

The operating sequence of the machine is schematically illustrated in Figure 1. Prior to casting, the tundish is preheated with the flame emerging from the tundish nozzle serving to preheat the mold plug. On completion of heating, the mold is pushed over the tundish nozzle into the casting position. Metal is poured from the melting furnace into the preheated tundish and flows through the tundish nozzle into the mold cavity. After a delay of a few seconds to allow freezing onto the anchor bolts of the tundish nozzle, the mold is slowly withdrawn from the fixed nozzle and gradually accelerated to the final casting speed. As casting proceeds, the metal level in the tundish falls to a point at or below the level of the tundish nozzle. Casting is complete when all the liquid core has been converted to a solidified outer shell.

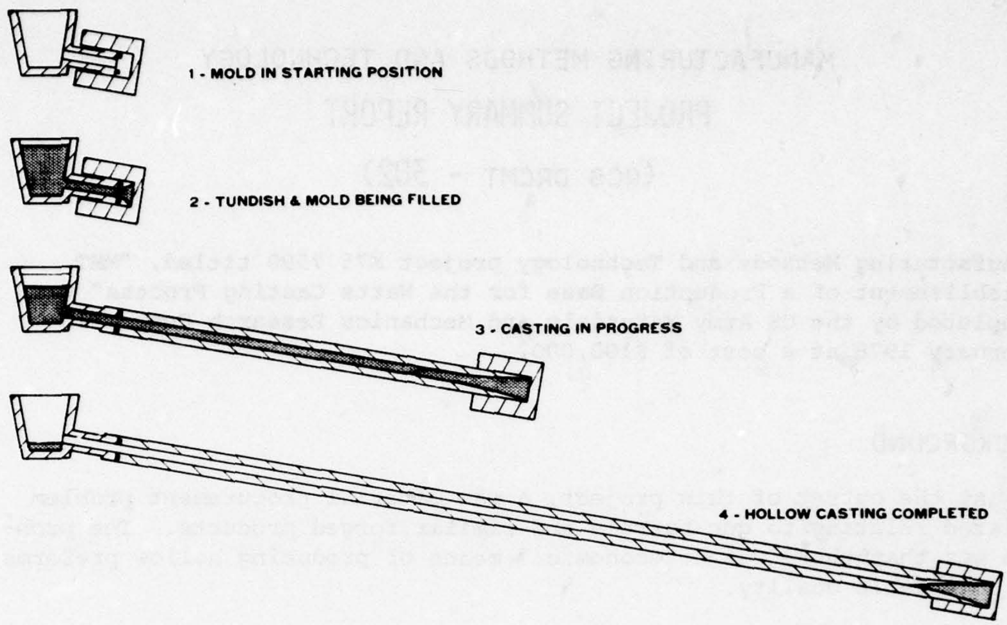

Figure 1 - Operating Sequence of Horizontal Tube Blank Caster

This phase of the effort was completed with all final design drawings and a technical report submitted to AMMRC.

BENEFITS

This project was completed with the provision of a complete data package for construction of a Watts casting machine to produce hollow gun barrel forging blanks.

IMPLEMENTATION

The planned implementation, or construction of the prototype, was pursued under Project M78 7590; however, the response to R.F.Q.'s was in excess of available funds and the Phase II project was cancelled.

MORE INFORMATION

Additional information may be obtained by contacting the project officer, Arthur Ayvazian at AV 955-3233 or Comercial (617) 923-3233.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 175 7036 titled, "Isothermal Roll-Forging Compressor Blades" was completed by the US Army Aviation Systems R&D Command in December 1977 at a cost of $205,000.

BACKGROUND

At the time of inception of this effort, R&D studies by private industry had shown that isothermal roll-forging could be applied to the manufacture of compressor blades. Experience had shown that the process could produce the finish and precision of cold roll-forging in a single operation, and the potential for savings and other advantages was recognized. A schematic of the roll-forge machine where the workpiece and dies are heated by a controlled flow of electric current through the area of contact is shown in Figure 1.

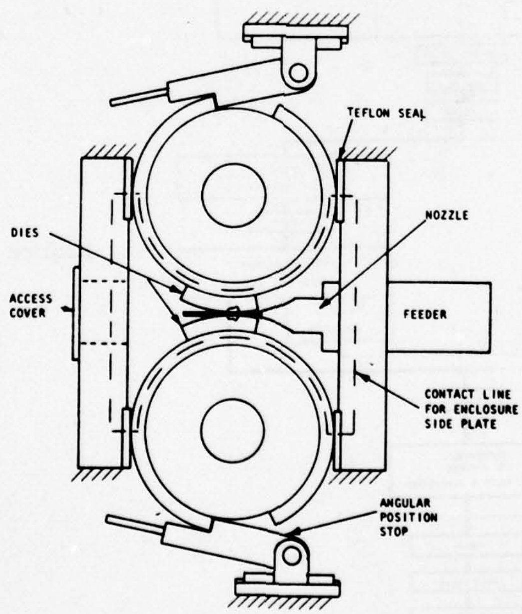

Figure 1 - Schematic of the Roll-Forge Machine

SUMMARY

This project was the first phase of a three-phase program with funding in fiscal years 75, 78, 79, and 81. The objectives of this first phase were: a) to demonstrate the capability of the process by making a second stage compressor blade of the Lycoming T-55-L-11A engine to within 0.010 inch of the nominal drawing dimensions, and b) to gain experience with tooling and processing that would enable prototype blade production within drawing tolerances during Phase II. At the beginning of Phase I, several approaches to blade manufacture were identified, based on various methods of preform formation, rough and finish roll-forging, and finishing. After six months of forging trials and process selections, the approaches to blade manufacture evolved as depicted in the following flow chart, Figure 2. The process sequence selected as best for the T55 second stage blade using AM-350 material is shown by the heavy line.

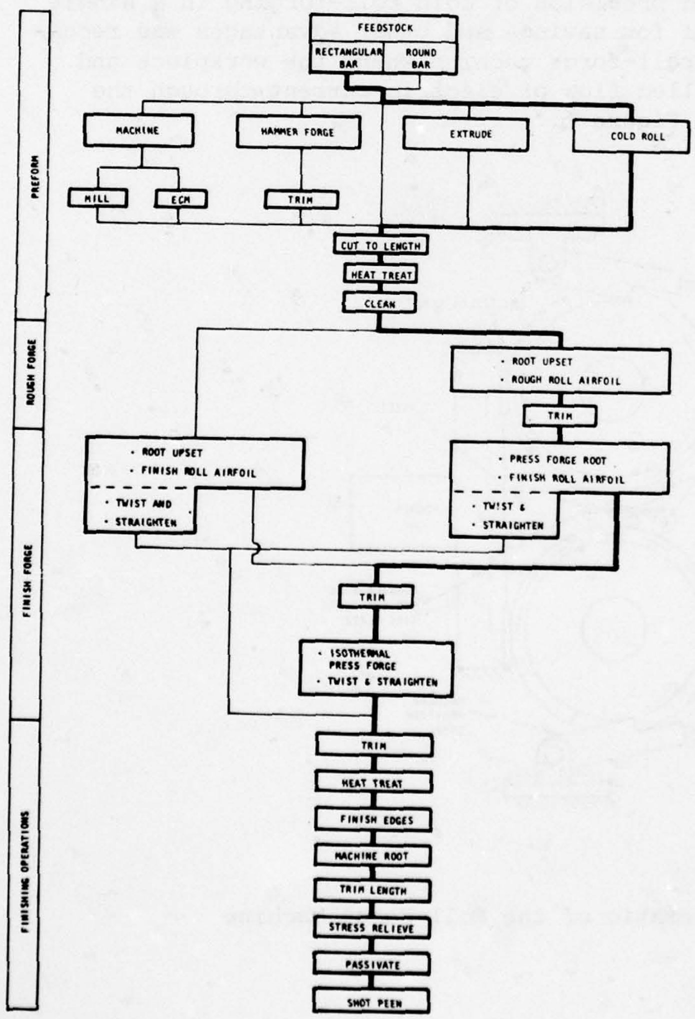

Figure 2 - Flow Chart

The most critical areas on a compressor blade are at the transition radii from the platform to the airfoil. Defects in this region such as (hot) forging laps or undercuts from handwork are most frequently associated with blade failures. One of the objectives of the isothermal roll-forging method is the elimination of laps and hand work, which this process is expected to accomplish.

BENEFITS

In this first phase effort the capability of the process was demonstrated, the method was developed, and the best process sequence was selected. These accomplishments are prerequisite milestones of a continuing effort which is expected to yield significant improvements in reliability and cost.

IMPLEMENTATION

Phase I interim technical report, AVRADCOM Report No. 77-11 dated December 1977, has been prepared and distributed. Data and other developments have been incorporated in Phase II.

MORE INFORMATION

Additional information can be obtained by contacting Mr. Roger Gagne, AV 955-3436 or Commercial (617) 923-3436.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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MANUFACTURING METHODS AND TECHNOLOGY. PROJECT SUMMARY REPORTS.(U)

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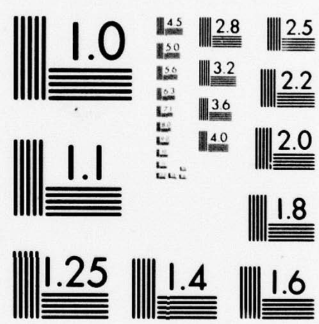

MICROCOPY RESOLUTION TEST CHART
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MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 176 7055 titled, "Ultrasonic Welding of Helicopter Secondary Fuselage Structures" was completed by the US Army Aviations Research and Development Command in October 1977 at a cost of $180,000.

BACKGROUND

This work was undertaken to optimize the ultrasonic welding process and techniques and to verify the potential savings by ultrasonic welding of helicopter secondary fuselage structures. Prior work was completed by Aeroprojects, Inc. with company funds and also under MMT project 172 8037 titled, "Sonic's in Metalworking".

SUMMARY

This project was a joint effort of Sonobond Corporation and Hughes Helicopters under the sponsorship of AVRADCOM. The objective of this project was to demonstrate the effectiveness of the ultrasonic welding of secondary fuselage structures, and to prepare a specification for the manufacturing process and the ultrasonic welding machine. To implement these objectives, ultrasonic spot welds were made in several thickness combinations of 2024T3 and 6061T6 Alclad, and in several thicknesses of 6Al-4V titanium. These coupons were evaluated by tensile shear tests, fatigue tests, salt spray tests, and metallographic examination. The significant results were that the tensile shear strengths of ultrasonic spot welds were 2.5 times those of resistance spot welds, and about four times the minimum average required by MIL-W-6858B.

Next, a secondary structure, the port side electronic access door of the YAH-64 helicopter was selected, redesigned for ultrasonic welding, assembled, and subsequently tested. This door was originally assembled by the adhesive bonding of an inner and outer skin to a 0.75-inch aluminum honeycomb core. It weighed 5.5 pounds. After the redesign, it weighed 3.3 pounds, or a reduction of 40%. Four such units were assembled with on center weld spacings of 3.0 inches, 2.0 inches, 1.50 inches, and 1.25 inches. These units withstood measured loads of five to ten times the aerodynamic design load. The weld spacing of 1.5 inches was selcted as the optimum from the standpoint of the strength to cost effectiveness tradeoff. Figure 1 depicts the basic door. As illustrated, the aircraft has six access doors which require welding.

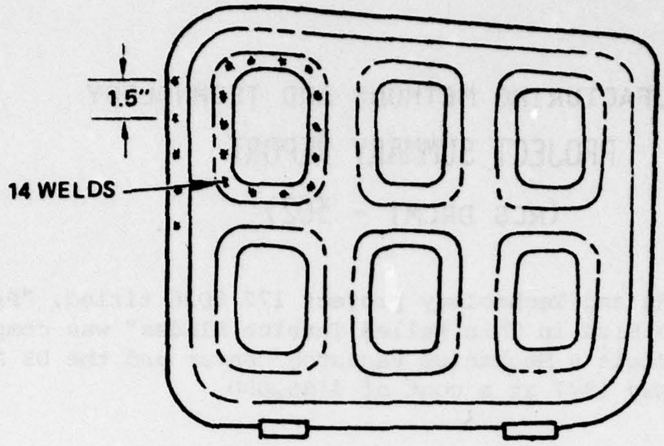


Figure 1 - Port side electronic access door showing ultrasonic weld spacing.

BENEFITS

The labor for an adhesive bonded door costs $68 while an ultrasonically bonded door costs $17. The total labor cost savings anticipated from a production run of 535 aircraft would be approximately $163,000. Energy savings are likewise impressive. A four-hour cure in an oven for the adhesive bonded door incures an energy cost of $19.35 per door. The corresponding energy charge for the ultrasonically welded door is $0.008. The energy savings for 535 aircraft would be approximatley $62,000. The combined program saving totals over $225,000. A reduction in weight is another intangible benefit.

IMPLEMENTATION

This is the first phase of a two year effort which demonstrated the effectiveness of ultrasonic welding and established the process specification for non-structural and secondary structural assemblies. A design change for the access doors is being implemented by Hughes Helicopter. The second phase, under project 178 7055 will deal with primary fuselage structures and will provide the process specification and an ultrasonic welding machine in the helicopter manufacturers plant.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Gene Glover, HQ, AVRADCOM, AV 698-6476 or Commercial (314) 268-6476.

Summary Report prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 172 8036 titled, "Process for Controlled Grain Size in Thin Walled Turbine Blades" was completed by the US Army Materials & Mechanics Research Center and the US Aviation Systems Command in May 1977 at a cost of $185,000.

BACKGROUND

At the inception of this project, new turbine designs were calling for the use of thin (.010 - .015") turbine blades. Investment casting was the most economical method of manufacturing such parts; however, state-of-the-art thin wall investment castings did not meet the high temperature properties required.

SUMMARY

The objective of this project was to establish and provide the technology and solidification techniques needed to control the microstructure of high temperature alloys in order to improve the mechanical performance of turbine wheel castings. High temperature mechanical properties decrease as blade thickness decreases because when there are only two or three grains across the blade thickness and fractures are intergranular, the mechanical properties become dependant on the grain orientation. Figures 1 and 2 depict the cause and manifestation of thermal fatigue. The following photomicrograph, Figure 3, shows a typical turbine blade cross section with only two to three grains across the entire blade thickness.

In this project, the influence of refinement of the cast grains on the mechanical properties of three nickel base superalloys (713C, MAR-M-246 and C103) was determined. The grain refining techniques, established on a laboratory basis, were then successfully translated to the production of T-63 first stage rotors, utilizing regular production investment molds, melting, and casting facilities.

The alteration in the process to achieve grain refinement were the addition of 0.1% boron, thermal cycling between 2800°F, and the melting temperature, pouring with 100°F super heat, and increasing the mold temperature from 1800°F to 2100°F. These changes increased process time from a total of six minutes to eighteen minutes.

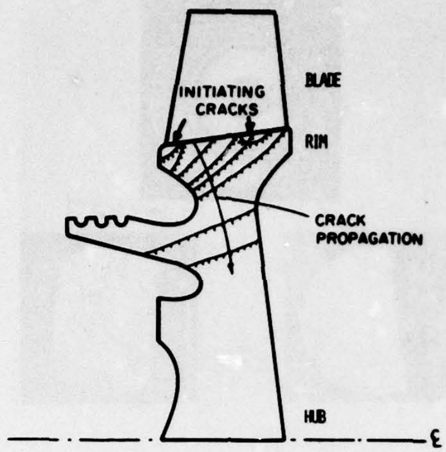


Figure 1 - Schematic Cross Section of Turbine Rotor Showing Hub, Rim, and Blade Areas, Indicating Initiating Cracks

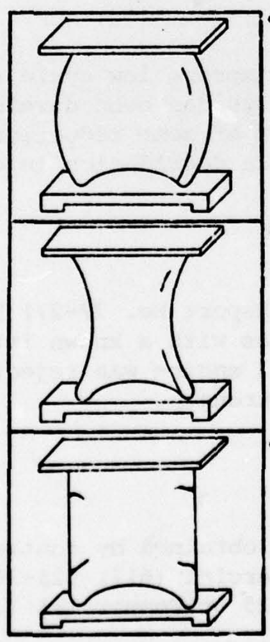


Figure 2 - Sequence of events leading to the development of thermal fatigue cracks in gas turbine blades.

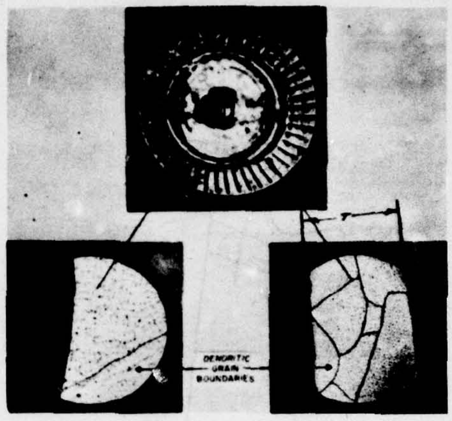


Figure 3 - Turbine Wheel, AS-CAST, 713-LC Macroetched

The project demonstrated that grain refinement of integrally cast, turbine rotors is commercially feasible. These grain refined rotors had superior fatigue properties while still retaining adequate stress properties under service conditions.

BENEFITS

A method to refine grain and improve low cycle fatigue properties of certain cast nickel base superalloys has been developed. However, these benefits were obtained at the cost of some reduction in casting yield due to the low super heat, as well as a degradation in creep strength.

IMPLEMENTATION

The technical report (AVSCOM Report No. 77-27) has been distributed to foundries and aircraft companies with a known interest in the program. Planned implementation in the T-63 engine was rejected by the contractor due to the degradation in creep strength.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Perry R. Smoot, AMMRC, AV 955-3474 or Commercial (617) 923-3474; or Mr. Randy Gutscher, HQ, AVRADCOM, AV 693-1625 or Commercial (314) 263-1625.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 473 4257 titled, "Methods for Forging Large Cast Armor Preforms" was completed by the US Army Tank-Automotive Research and Development Command in February 1977 at a cost of $375,000.

BACKGROUND

At the time this project was introduced, the method of producing an M60A1 tank hull was by casting. Even though the best casting practices were utilized, normal cast metal ballistic quality was below that found in wrought metal plate. Consequently, the use of cast armor required greater thicknesses, and hence, weight for equal protection. Previous forging development work had indicated that forged tank hull front ends formed from cast preforms could be manufactured and would yield ballistic properties superior to cast parts of equal weight, or, would permit an approximate 10% reduction in weight with equal ballistic protection.

SUMMARY

This project was the third of a three phase program with the initial phase commencing in FY69. The objective of this phase was to demonstrate the feasibility of volume manufacture using the technique previously developed. The final end products of the effort were to have been manufacturing process data and all related engineering data needed to produce the end product. The evaluation included: a production run of eight hull fronts, a definition of the process, the establishment of initial production rates and applicable costs, the determination of the dimensional, mechanical, and ballistic properties, and an evaluation of die life. Fiures 1 and 2 show the cast preforms and a finished forging, respectively. Conclusions and recommendations were as follows:

a. The projected cost (in 1977 dollars) of a 10,530 pound cast preform was $9955. Processing costs, at a production rate of six per hour, including G&A and Profit, was estimated at $7931. The combined total cost was $17,886 each or $1.69 per pound.

b. A press capacity of 35,000 tons was found to be adequate for final forging of the end item.

c. Dimensional problems still existed for this nonsymetrical configuration; however, there would be no problem on items which are symetrical and free of re-entrant angles.

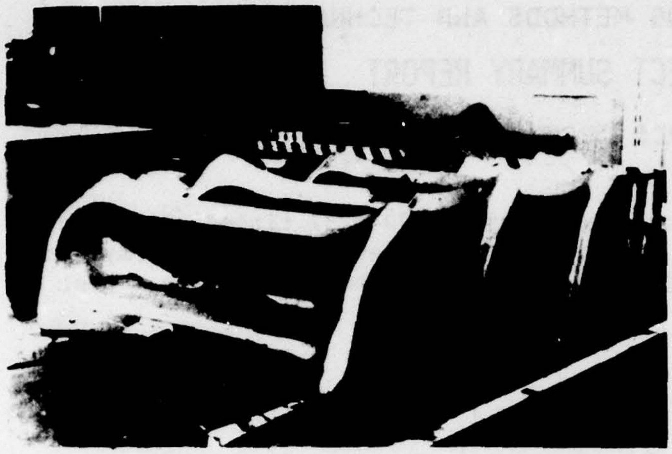


Figure 1 - Cast Preform

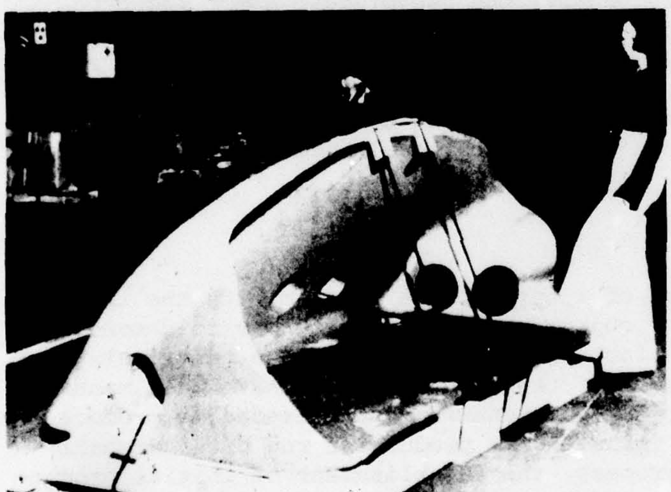


Figure 2 - Finished Forging

D. Die wear proved to be neglible; however, overall die life could be reduced by the severe side loads that this nonsymetrical design generated.

e. Forgings given a normalizing heat treatment in addition to the conventional hardening and tempering were found to have better toughness properties.

BENEFITS

The procedures for a new method of manufacturing large complex armor structures was established. This method provided:

a. Low cost high volume production capability

b. Ballistic improvement over casting

c. Reduced inspection cost

d. Lower scrap and rework

e. Greater uniformity from part to part

IMPLEMENTATION

The process is no longer applicable to the M60 hull in its present configuration; and with the advent of the XM1, the cost of redesign and retooling could not be justified. Several armor areas on the XM1 vehicle (GM Prototype) were potential candidates for manufacture by this method; however, the selected Chrysler design has no such application. For this reason, no implementation is envisioned.

MORE INFORMATION

Additional information can be obtained by referring to TARADCOM Technical Report No. 12210 titled, "Methodology for Forging Large Cast Armor Preforms" dated February 1977 or Technical Report No. 11981 titled, "Production Practice for Forging Large Armor Sections from Cast Armor Preforms" dated November 1974, or by contacting the project officer, Mr. Harry Spiro, AV 273-1389 or Commercial (313) 573-1389.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 473 4382 titled, "Open Arc Gasless Welding" was completed by the US Army Tank-Automotive R&D Command in January 1977 at a cost of $150,000.

BACKGROUND

Shielding gases of various types have been utilized to protect the weld pool from contamination in metal inert gas (MIG) welding since the advent of the process. This gas has most typically been argon or mixtures of argon and carbon dioxide. An objectionable feature of this process is the cost of the shielding gas and the logistics of providing the right kind for the application at hand, especially in the field. One alternative to the MIG process has been the use of externally coated weld electrodes, which protected the weld pool with gaseous products and slag from the coating. But this older process, though obviating the need for a shielding gas is a slower, and therefore, more costly process, due in part to the lack of an automatic wire feed. Additionally, each electrode must be manually replaced when it is partially consumed, and the unused portion discarded. To overcome the shielding gas requirement of the MIG system and the labor and material costs associated with externally coated electrodes, a method which appeared likely to accomplish these requirements was selected for investigation.

This project was the second year of a two year effort to provide a more cost effective alternative to present methods.

SUMMARY

The method selected for investigation is one that utilizes a welding electrode which has an inner core of chemical ingredients. This core produces gaseous shielding and slag when decomposed by the arc ($CaCO_3$ CaO slag + CO_2 shielding). Since the chemical is inside, the welding electrode can be obtained as coils of wire which can be controlled by a standard automatic wire feed similar to that used in the MIG process.

Phase I (project 472 4382) determined optimum weld joint geometries and welding parameters for producing sound welds in armor. This project (Phase II) had as an objective the sample preparation and testing to determine whether the process was capable of producing satisfactory welds in armor. X-shaped samples were fabricated from 1/2, 3/4, 1, and 1-1/2 inch rolled armor plate to determine weld characteristics under restrained

joint conditions, Figure 1. I-plate samples (Butt joints) were prepared using double V-groove geometry, Figure 2. All welds were X-rayed and checked for cracks with die penetrant. Samples for ballistic testing were also prepared and tested at Aberdeen Proving Ground.

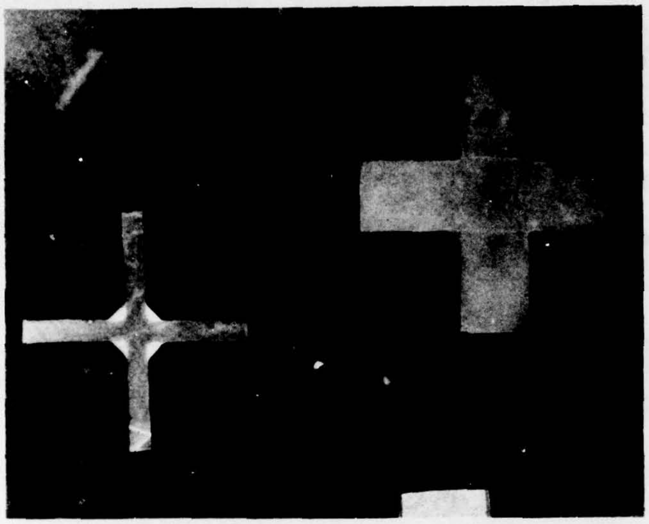


Figure 1 - X-shaped weld samples of 1/2, 3/4, 1, and 1-1/2 inch thick armor plate.

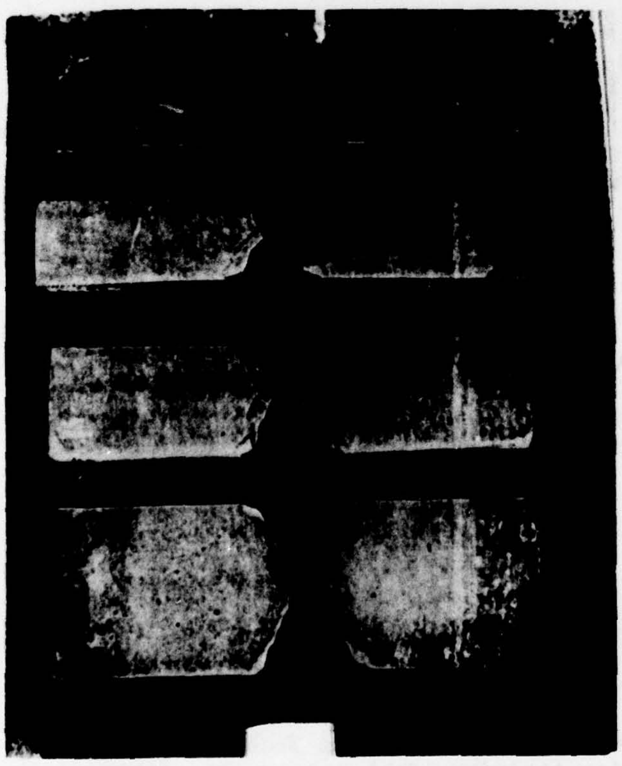


Figure 2 - I-plate weld samples of 1/2, 3/4, 1, and 1-1/2 inch thick armor plates.

The conclusions drawn from this effort were as follows:

a. This process provided adequate "self-shielding" to produce welds free of atmospheric contamination.

b. The process would be ideal for welding in the field where ballistic weld quality is not required.

c. Welds produced in armor plate joint geometries were marginal due to slag entrapment. This problem was almost entirely alleviated when the root opening or minimum spacing between parts was increased to 1/4 inch.

d. The process generated excessive smoke which had to be removed in order to see the weld pool.

BENEFITS

Although this project has not resulted in a process useable for the production of armored vehicles, it did demonstrate the potential effectiveness of flux cored electrodes in heavy weldments where joint geometries are less restrained than those found in armor vehicle welds. Welding systems using flux cored welding electrodes are now well established in industry, and these types of electrodes are available in a variety of materials.

IMPLEMENTATION

The TARADCOM Technical Report No. 12148 titled, "Open Arc Gasless Welding" by Eugene Balla was issued in January 1977. No further action is contemplated; however, this process would be ideal for heavy welding in the field. Sections as heavy as 1-1/2 inches thick were successfully welded with proper joint preparation and multiple passes, as shown in Figures 1 and 2.

MORE INFORMATION

Additional information may be obtained by contacting Eugene Balla, AV 273-2467 or Commercial (313) 573-2467.

Summary Report prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 475 4391 titled, "Isothermal Heat Treatment for High Strength Ductile Iron Castings (Phase II)" was completed by the US Army Tank-Automotive Research and Development Command in September 1978 at a cost of $150,000.

BACKGROUND

Phase I of this effort explored the casting and isothermal heat treatment of ductile iron alloys containing varying levels of nickel. The objectives were the development of a material substitute for alloy steel forgings used in critical armored vehicle components, and realization of the associated manufacturing economies.

An improved ductile cast iron was developed, which exhibited substantial promise when tested in the laboratory. This material was an isothermally heat treated ductile cast iron containing 0.75% nickel.

On the strength of these results, test components were prepared for the M113 armored Personnel Carrier, consisting of track shoes, suspension arms and sprockets.

SUMMARY

In Phase II of the program, the experimental material in the form of T130E1 track shoes was vehicle-tested in an M113A1 Armored Personnel Carrier (APC) at US Army Yuma Proving Ground and US Army Cold Regions Test Center. Standard Components were also installed and tested as a reference.

The Yuma test was run for 5486 miles, during which 14 of the 63 ductile iron shoes cracked; none of the standard shoes cracked. The ductile iron sprockets showed more wear than the standard sprockets. The test which was scheduled for 6000 miles was terminated due to failure of the right final drive on the M113A1 APC.

The Cold Region test was run for about 828 miles during which 22 of the 64 ductile iron track shoes and one of the three ductile iron sprockets broke. There were no failures of the standard components. Since only one extra test shoe was provided, and broken test shoes were being replaced with standard track shoes, the test was becoming less and less statistically significant. It was therefore terminated before the scheduled 2000 miles of testing were completed. See Figures 1, 2, and 3 for examples of failures experienced.

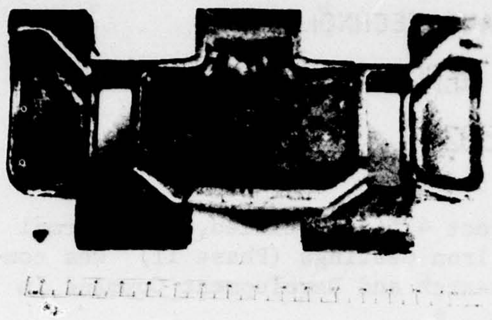


Figure 1 - Broken Shoe

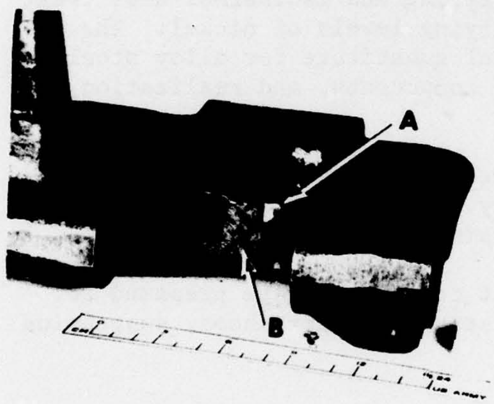


Figure 2 - Cracked Shoe

Figure 3 - Broken Sprocket

The conclusions drawn from these tests were: a) the durability of the isothermally heat treated cast ductile iron track shoes and sprockets was inferior to that of standard components, and b) the test components were not suitable for low temperature applications.

The heat treatment which was developed resulted in a ductile iron that obtained an ultimate tensile strength of 135 KSI, yield strength of 97 KSI and elongation of 11%. The low temperature (-40°F) Charpy impact toughness was 3 FT-LBS, and rotational bending fatigue strength was 62.5 KSI at room temperature.

BENEFITS

Due to the failure of the components during operational testing, the anticipated benefits of developing a manufacturing process for ductile iron castings were not realized. Although unsuited for the application tested, future beneficial applications of this material could result if it is used in less demanding applications.

IMPLEMENTATION

With the failure of the components under test conditions, the requirement for implementation was voided.

MORE INFORMATION

Additional information on this project is available from Mr. K. F. Chesney, TARADCOM, Warren, MI, AV 273-1814 or Commercial (313) 573-1814. Reference TACOM Technical Report No. 12350, September 1978.

Summary Report prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 572 6335 titled, "High Strength Aluminum Alloy Shapes by Powder Metallurgy" was completed by Frankford Arsenal in April 1977 at a cost of $440,000.

BACKGROUND

Engineering components manufactured by the usual powder metallurgy (P/M) approach of pressing and sintering have lower physcial properties than wrought or cast components of the same composition. The lower properties are attributed to high residual porosity.

Increasing the density and thereby increasing the mechanical properties would enable new applications offering substantial benefits in labor and material cost reductions.

SUMMARY

The objective of this project was to establish the manufacturing technology required to produce aluminum alloy shapes from 3200 pound powder compacts. These shapes were expected to have superior combinations of engineering properties to enable weight/thickness/volume reductions in munition items and to thereby increase the effective capacity.

Initially, the process to be scaled up was to be the same as that developed in the laboratory; however, after encountering significant density and tooling problems associated with the cold compaction operation, the process was revised to that oulined in Figure 1. For a broader perspective regarding this process, see also Figure 2 which shows the relative size of the hot compaction tooling used in conjunction with a 35,000 ton hydraulic press. The scaled up process started with atomized alloy powder being preheated and vacuum hot pressed to fully dense billets. These billets were then subjected to further production mill conversion into plate, extrusions, and die forgings. The resulting engineering properties of these products indicated that P/M plate was equivalent to the lab-produced plate; and developed 13% higher strength, equal toughness, 30-50% higher notched fatigue strength, and superior exfoliation corrosion and stress corrosion cracking as compared to the existing commercial ingot metallurgy (I/M) alloys. Scaled up P/M extrusions and die forgings were weaker than the earlier lab scale products but still developed superior stress corrosion resistance,

30-80% higher notched fatigue strength, and strength/tougheness of extrusions comparable to 7075 and nearly equal to 7050. The strength/toughness of die forgings was equal to 7050 and superior to 7075. An Alcoa-funded follow-on study was initiated to further develop the process and enhance the engineering properties.

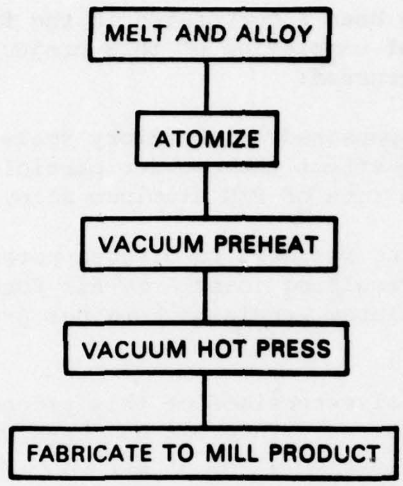


Figure 1 - P/M Process

Figure 2 - Assembled Hot Compacting Tools

BENEFITS

A new production process has been developed which results in materials having properties superior to those of materials previously available.

IMPLEMENTATION

The data generated have been incorporated in the final report number FA-TR-76067. At the time of completion of this project, the following action items had already occurred:

a. The Air Force had sponsored a laboratory scale (170 pound) research project to study the effect that powder particle morphology has on the fatigue crack growth rate of P/M aluminum alloy forgings.

b. A tri-service meeting was held to discuss potential jointly supported P/M projects. One resulting joint Army-Air Force program is the Aluminum Alloy Powder Metallurgy Precision Forgings project which is presently on-going.

Many tangents and logical extensions of this process, such as direct rolling of powder, have occurred. Interest has been widespread among the Services. In-house efforts are underway at Reynolds, Gould, International Nickel and Alcoa to fully exploit this development in its commercial applications.

Alcoa, under contract to AMMRC, is continuing an R&D effort to further optimize the engineering properties of extrusion and die forgings.

MORE INFORMATION

Additional and more detailed information may be obtained by reviewing the technical report no. FA-TR-76067 dated 25 April 1977, titled, "Program to Develop High Strength Aluminum Powder Metallurgy Mill Products" or by contacting Dr. Jeffrey Waldman at AV 880-5811 or Commercial (201) 328-5811.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT - 302)

Manufacturing Methods and Technology project 573 6550 titled, "Engineering in Support of Artillery Metal Parts Modernization Program" was completed by the Frankford Arsenal, US Army Armament Research & Development Command in May 1977 at a cost of $480,187.

BACKGROUND

At the start of the Army modernization program, for projectiles and metal parts facilities, it appeared that many existing facilities were implementing programs without fully considering an integrated approach to modernization. This study was initiated to identify the status of the manufacturing art in existing facilities and establish areas where improvements could be made.

SUMMARY

The objective of this project was to develop manufacturing processes, techniques, and equipment for use in production of Army material. The project had as its purpose a study of manufacturing art in existing facilities, suggesting areas where improvements could be made either directly or, when necessary, through the implementation of MMT programs.

Investigations were undertaken to assist in the determination of what process modifications, changes, and studies were necessary for artillery metal parts plant modernization. Investigations included: literature survey, state-of-the-art studies, plant surveys, warm form study, ceramic tool study, solid state switching study, chip transport study, development of a math model for forming, and feasibility of heat treatment by induction.

Surveys were made of nine metal parts manufacturing plants to determine areas where improvement could be made. Project accomplishments for this effort were too numerous to include in detail in this report; therefore, only three examples were selected to demonstrate typical accomplishments.

At one manufacturing facility of 155mm M107 projectiles, a contractor was using manual loading and unloading for material handling of projectiles at each press and machine operation. This plant converted to an integrated automatic forge press line which reduced the required number of

personnel from eight full time personnel in the old system, to only one full time person plus a tool setup person approximatley half-time for the new automated system. The line rate of production also changed from 125 units per hour for the old system to 180 units per hour with the new automated material handling system. This resulted in a reduction of 0.0556 manhours per unit produced, while increasing the production rate from 15.625 units per manhour to 120 units per manhour.

Substantial energy savings resulted in the area of metal forming operations at another facility. These savings were brought about by the replacement of five mechanical forge presses and 10 hydraulic draw presses by five larger mechanical presses, capable of performing the draw as a part of the forging operation. These press replacements reduced the horsepower usage from 10,000 HP required by the initial 15 presses to 2,750 HP required by the five new presses, a reduction of 7,250 HP.

In a third example, a hydraulic transfer system for loading and unloading 42 lathes required a total of 1,680 HP operating continuously to maintain a constant dead head hydraulic pressure. This system was replaced by 42 non-hydraulic transfer units having a total of 315 HP which were required to operate only during actual transfer operations, approximately 10% of the cycle time, thereby resulting in an operating usage of only 31.5 HP. This new transfer unit provided an energy savings of 1648.5 operating horsepower.

BENEFITS

The benefits realized from the results of this effort are cost savings, energy savings, sole source elimination, and improved readiness.

IMPLEMENTATION

Improvements have been implemented in the modernization of metal parts plants, such as Scranton AAP, Twin Cities AAP, and Louisianna AAP.

Additional benefits from this project will be accrued through several MMT projects which have been implemented as a result of the recommendations of this study.

MORE INFORMATION

Additional information on this project is available from Mr. Robert J. Stock, AV 348-5323 or Commercial (215) 831-5323, Frankford Arsenal, Philadelphia, PA 19137.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 674 6771 titled, "Design and Construction of a Refined Step Threading Machine" was completed by Watervliet Arsenal in June 1977 at a cost of $195,000.

BACKGROUND

This work was undertaken to reduce the direct and indirect costs of machining the internal threads of the breech ring and the external threads of the breech block. The initial effort began in fiscal year 1969 with a project that resulted in a machine to thread the breech ring, equipped with only the elements essential for machining to the semi-finished state. Nonetheless, overall machining time was reduced by over six hours as a result of this effort. With 1970 funding, a machine for the external threads of breech blocks was provided. This machine also contained only the essential elements for machining to the semi-finished state. The most recent prior effort, using FY71 funds, resulted in an improved breech block threader which reduced the machining time from over seven hours, by the original method, to two hours.

SUMMARY

The objective of this project was to provide a refined rotary thread shaper, tooling and fixturing to machine the step thread on breech rings to finished size; and also to provide operational procedures and training of manufacturing personnel. This project is directly related to 669 6771 which resulted in a machine tool that produced two diametrically opposed threaded segments, with all thirteen threads of each segment formed simultaneously. But since this first machine had no precise size control and no provision for gaging while the part was still in the machine, the parts had to be removed, gaged and then finished by the old process. Figure 1 shows the ring removed from the shaper for checking prior to finish machining, which is shown in Figure 2. This project provided a machine based on the original concept, Figure 3, but with all the features required to perform the entire operation without removing the part for gaging and without a separate finishing operation. The prototype machine is shown in Figure 4.

Figure 1 - 1755mm M113 Breech Ring Checking Thread Location Prior to Finish Machining

Figure 2 - Step Threading Lathe for Finishing Machining Step Threads

STEP THREADING MACHINE

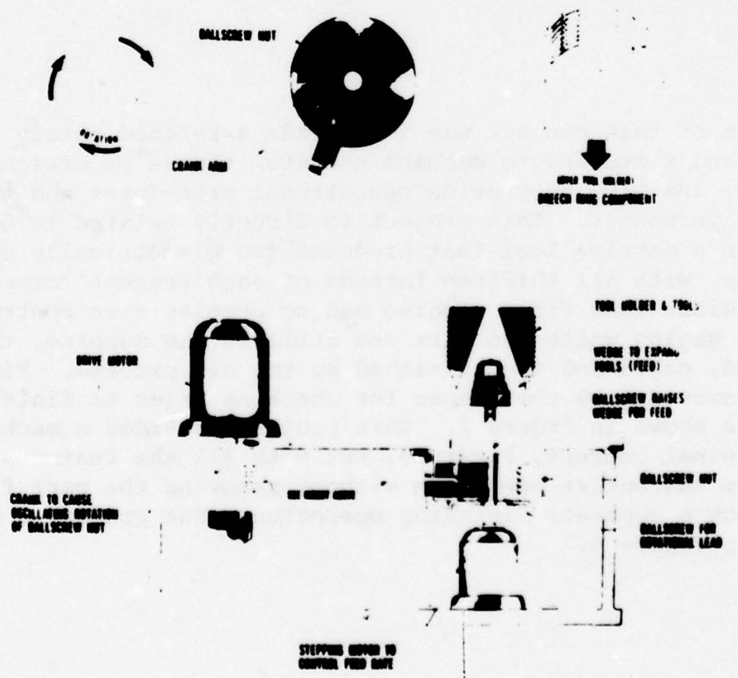


Figure 3 - Concept

Figure 4 - Spindle of Prototype Step Threader Showing Opposed Cutting Tools.

BENEFITS

Thread shaping produces components that meet all the drawing criteria with a surface finish superior to breech rings produced by the old method. The step threading operation on breech rings which originally took 13 hours can now be done in four hours. At $30 per hour, this amounts to a reduction in unit cost of $270. Of these reductions, three hours or $90 per piece are due to the elimination of the finishing operation. Work in process inventory can also be reduced because of the reduction in lead time.

IMPLEMENTATION

Implementation has been completed. The machine has been moved to the 175mm/8" breech ring production line and is currently being used in production.

MORE INFORMATION

Additional information may be obtained by contacting Mr. C. H. Rose, AV 974-5611 or Commercial (518) 266-5611.

Summary Report prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 673 7104 titled, "Homogenization of Critical Steel Castings" was completed by US Army Materials & Mechanics Research Center and Watervliet Arsenal in January 1978 at a cost of $85,000.

BACKGROUND

The ductility and toughness specifications of certain high-strength cast steel components were very difficult for contractors to attain. Consequent high scrap losses had induced a disinclination on the part of contractors to supply these items. This project was the last of a three-year effort to provide the processing parameters needed to develop the required ductility and toughness properties.

SUMMARY

In FY71, a high temperature car bottom vacuum furnace was acquired and some typical, critical components were processed. In FY72, other components such as couplings, breech rings, muzzle brakes, spindles, and carriers were processed and tested and processing technology was developed for each type of component. In this project, it was planned to prepare processing documentation and quality assurance engineering information needed for the manufacture of this casting group. Figure 1 shows the high temperature vacuum furnace used in the studies.

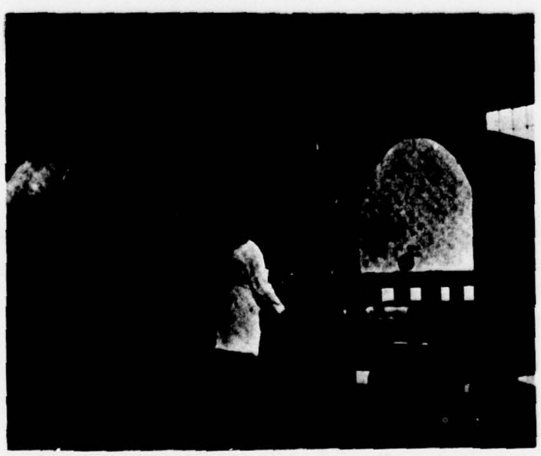
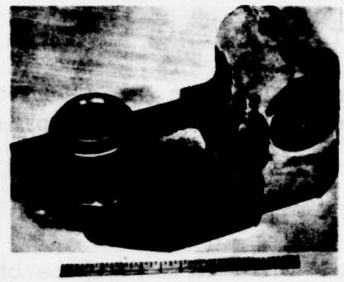


Figure 1 - High temperature vacuum furnace used in studies.

Four different types of castings, the compositions of which ranged from low alloy to medium alloy steels, were homogenized at 2400^{o}F for periods of 32 and 64 hours. See Figure 2 for types of items homogenized.

a. Drawbar ring coupler (lunette)
19-088-1107/AMC-72



b. 155-mm M126 housing

c. 155-mm XM199 muzzle brake

d. 152-mm XM150E5 coupling

Figure 2 - Components used in homogenization studies

After austenitization and tempering, substantial increases were observed in the ducitility and toughness properties. All tested components indicated that property improvements can be realized from homogenization, but due to various factors such as steel composition, subsequent heat treatments, and required mechanical properties, the conditions necessary to get the maximum benefits were not always the same. Comparison and analysis of the data did not show strict relationships between the different variables and the resulting properties. For this reason, the results were not as conclusive as was originally contemplated.

BENEFITS

While the homogenization did yield positive results, the benefits were not great enough nor sufficiently predictable to justify the increased energy costs associated with the long cycle homogenization heat treatments.

IMPLEMENTATION

The Technical Report No. AMMRC-TR-78-1 was issued January 1978. No further implementation is contemplated at this time.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Arthur M. Ayvazian, AV 955-3233 or Commercial (617) 923-3233.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 672 7119 titled, "Fabrication of Gun Barrel and Recoil Cylinders Through Optimization of Tooling" was completed by Watervliet Arsenal in December 1976 at a cost of $60,000.

BACKGROUND

The purpose of this effort was to improve the efficiency of machining cylindrical parts by optimizing turning tool geometry. Tests had shown that optimized geometries could yield substantially longer tool life.

SUMMARY

The objective of the project was to increase the efficiency and reduce the cost of turning commonly used weapon material such as 4340. This was to have been achieved by improving tool life and metal removal rates through scientific optimization of tool geometry.

Although the study resulted in verification of prior work and showed a marked rise in tool life on an experimental basis, both efforts indicated there was no advantage to pursue the procedures as a production tooling system.

Metal removal at Watervliet is performed with carbide tooling which is superior to the highest order of optimization possible with high speed steel (HSS) tools. Optimization of HSS resulted in unusual geometries. The optimization process applied to carbide also produces unusual geometry. The basis upon which most carbide tools are designed is indexability, or the capability of repositioning the tool insert to present fresh cutting edges to the workpiece until all available edges are worn out. Any deviation from symmetry reduces or eliminates the capability of tool indexing and therefore, reduces tool life from a potential of eight cutting edges to one edge. Since potential carbide tool life improvements were in the order of ten percent, it was concluded that no advantage could be gained by continued attempts to introduce this process to manufacturing, and that the currently used commercial standard provides the maximum economic advantage available at this time.

BENEFITS

The only benefit achieved was the confirmation that currently used commercial standards offer the maximum economic advantage.

IMPLEMENTATION

The technical report number WVT-CR-77003 has been distributed. No further implementation is contemplated.

MORE INFORMATION

Additional information may be obtained by contacting Mr. P.M. Casey, AV 974-5737 or Commercial (518) 266-5737, or by reviewing Technical Report WVT-CR-77003.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 676 7236 titled, "Application of Rapid Heat Treating to Cannon Tubes" was completed by Watervliet Arsenal in June 1978 at a cost of $190,000.

BACKGROUND

Traditionally, long soak times have been used by the heat treating industry to "homogenize" an alloy prior to quenching. A typical heat treatment of a 105mm M68 forging by a commercial vendor is as follows: "Heat to 1750°F in 10 hours, hold ten hours, air cool eight hours, reheat to 1525°F in ten hours, hold ten hours, water quench 13 minutes. Charge into tempering furnace at 500°F. Increase temperature to 1045°F on muzzle and 1055°F on breech in ten hours, hold twelve hours, water cool". This totals over 70 hours of furnace time. Such treatments are unnecessarily expensive in terms of capital equipment, labor, fuel and work in-process inventory due to long lead times.

SUMMARY

A recent study of gun steel concludes that tempering times for cannon tubes can be shortened considerably (Heiser, F., Heat Treating Gun Steel, WVT Technical Report ARLCB-TR-78006). Heat treating criteria established to compensate for limitations in equipment are no longer necessary with state-of-the-art furnaces and temperature measuring and control systems.

Eight rotary forged gun tubes were prepared for this study by implanting thermocouples at a mid-wall position of the breech end. These eight tubes were divided into samples of two tubes and six tubes and subjected to two different short time austenitization and tempering treatments. The heat-treated tubes were each sampled in four loactions to provide 16 tensile and 16 Charpy Impact samples from each tube. Figure 1 illustrates the sampling layout.

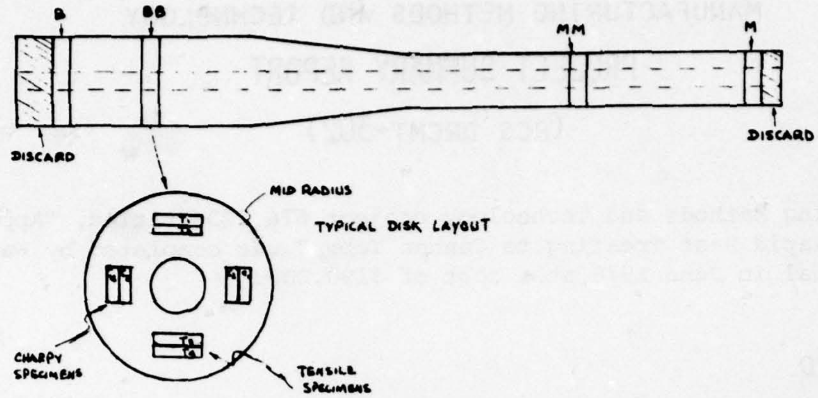


Figure 1 - Schematic of Mechanical Property Sampling Plan

The data gathered in this effort demonstrated that acceptable properties could be attained in full size gun tubes subjected to shortened austenitizing cycles. Heat treatment specifications were established for each cannon tube, which reduced the typical 70 hour furnace time to a range of 12-20 hours.

BENEFITS

Labor and overhead cost reductions of $43 per M68 tube and $71 per M185 tube have been realized. Significant but unquantified reduction in the use of fossil fuels has resulted. Future benefits from reduced bid prices and from in-house activities are anticipated. Capital expenditures for future heat treat capacity should also be reduced.

IMPLEMENTATION

Results have been implemented at Watervliet. The results of this program have been transmitted to other Government installations and interested private contractors.

MORE INFORMATION

Additional information on this project can be obtained from P. Thorton, AV 974-5249 or Commercial (518) 266-5249.

Summary Report prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT - 302)

Manufacturing Methods and Technology project 673 7242 titled, "Gun Tube Manufacture by Automation" was completed by Watervliet Arsenal in January 1978 at a cost of $195,000.

BACKGROUND

This work was undertaken in an attempt to reduce the cost of manufacturing gun tubes. It was initially thought that this could be best accomplished by the provision of a "consolidated automated tube line."

SUMMARY

It was determined in the earliest stages that this product was not a logical candidate for NC automation due to the high machining time to setup ratio. The basic premise of reducing cost and consolidating facilities was thereafter advanced by means of a flow-process analysis. This analysis provided the necessary information for a revised layout, consolidating the manufacturing process of M68 and M185 tubes under one roof. In addition, two other opportunities for improvement were revealed and acted upon.

The first of these involved the machining of the breech face extractor detail. Previous unsuccessful attempts to reduce the cost of this operation included electrochemical machining and profile duplication (Kellering). This attempt, using an existing 3-axis N/C machining center (CIM-X changer), was successful and reduced set-up and machining time by 60%, eliminated a production bottleneck and resulted in a more uniform product. Figure 1 shows a facsimile of the 105mm M68 breech mounted on the table of the N/C machine. Note the relief areas on the breech face, machined under numerical control.

The second operational improvement involved the grinding of the powder chamber of the 105mm, M68 tube. The previous practice for loading and unloading required the operator, using an overhead crane, to manually guide the gun tube through the hollow spindle and chucks to a positive locator stop. Because of the ungainliness and weight of the tube, damage to chuck jaws and locator stops were common occurrances. Figure 2 shows the newly designed and built tube loading assembly attached to the powder chamber grinder. This loading assembly consists of a vee-notched

cradle mounted on rails. The gun tube is supported by the cradle as it is conveyed down the rails and into position for the grinding operation. It should be noted that this loader could be used on any hollow spindle machine for boring or turning.

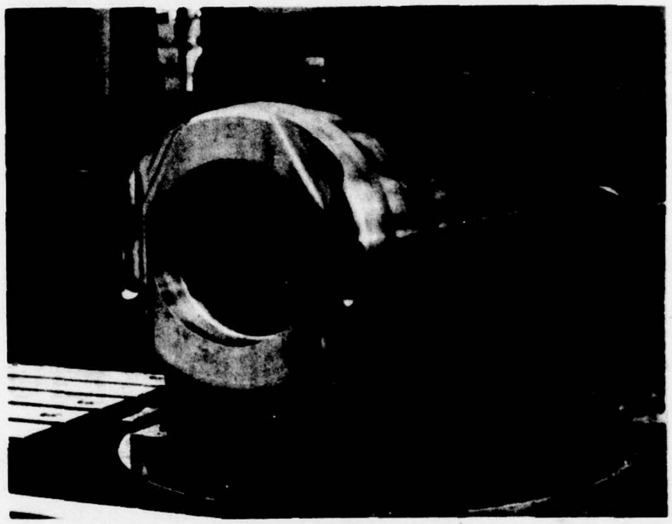


Figure 1 - N/C Machine with Facsimile of the 105mm M68 Breech Mounted on Table.

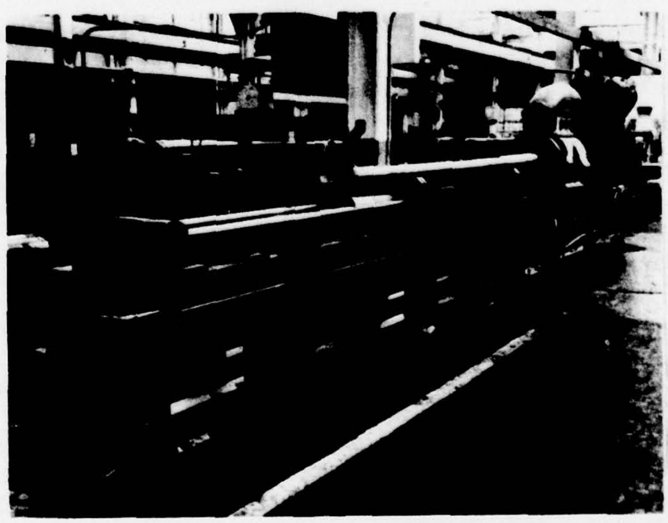


Figure 2 - Tube Loading Assembly to the Powder Chamber Grinder.

BENEFITS

The improved and consolidated layout has resulted in reductions in material handling, lead time and work-in-process inventory. Improved control of scheduling is probable.

The application of N/C machining to the breech face extractor detail resulted in labor and overhead savings of $69.68 per tube, which would amortize the capital equipment in 1.3 years.

The loading device resulted in a time saving of six minutes per tube or $2.50 per tube. Its primary advantages are that it eliminates damage, is safer, more accurate, and releases the crane for other use.

IMPLEMENTATION

Implementation was completed at Watervliet Arsenal by the following methods:

a. The improved manufacturing process of the 105mm M68 and the 155 mm M185 was implemented during the reorganized layout of IPE in the Medium Caliber Gun Shop, Building #35.

b. A Breech End Detail Machine was being acquired under project 675 6957.

c. A prototype powder chamber grinder loading device was designed, built, and installed and is now in daily use.

MORE INFORMATION

Additional information can be obtained by contacting C. La Ross, AV 974-5611 or Commercial (518) 266-5611.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 674 7495 titled, "Closed Die Forging of Powder Metal Preforms" was completed by the Rock Island Arsenal in December 1976 at a cost of $115,000.

BACKGROUND

The forging of metal powder preforms is a cost effective process for the production of small forged components. The chief benefits of the process are achieved through high material utilization and the elimination of many machining operations. It had been shown on a prior Army program that the properties of PM forgings are primarily dependent on the manufacturing process. It had also been demonstrated that by the proper selection of process parameters, PM forgings could be produced with ductility and impact properties comparable to wrought materials and suitable for ordnance components.

SUMMARY

This project was designed to evaluate the relative advantages of using hydraulic presses, mechanical presses, or drop hammers in a PM forging process suitable for the production of critical weapon components.

The program was based on the following guidelines:

a. The accelerator for the M85 machine gun was selected as the demonstration component.

b. 4600 prealloyed powder blended with sufficient carbon to form 4640 composition was used in the material.

c. Since the effects of process parameters had been established on prior programs, an evaluation of process parameters was deemed unnecessary.

d. Process parameters were selected which would produce a high quality product capable of meeting all metallurgical and dimensional specifications.

As a result of this effort, the manufacture of accelerators by PM forging was demonstrated. The mechanical crank type press was found to be superior to either the hydraulic press or the drop hammer in this application.

The economics of producing the M85 machine gun accelerator by this process is shown in Table 1. Most notable is the reduction in the number of machining operations from 27 to 7 and the reduction in material cost to about 17% of that previously experienced.

Conventional Process				Minimum Deformation P/M Process			
Operation	Standard Hrs/Pc	$/Pc	Setup Hrs	Operation	Standard Hrs/Pc	$/Pc	Setup Hrs
Heat & Forge	.0670	1.68	3.0	Compact	.0200	0.50	4.0
Trim	.0083	0.21	1.0	Sinter	.0025	0.06	-
Coin	.0083	0.21	1.0	Forge	.0200	0.50	3.0
Heat Treat	.1600	4.00	-	Heat Treat	.0800	2.00	-
Sandblast	.0300	0.75	-	S	.0300	0.75	-
Machine (27 Steps)	.8012	20.00	60.3	Machine (7 Steps)	.2699	6.75	13.6
Finish	.1882	4.70	1.1	Finish	.1882	4.70	1.1
Material	-	1.50	-	Materials	-	0.26	-
Totals	1.2630	33.05	66.4	Totals	.6106	15.52	24.7

Table 1 - Economics of Accelerator Production

During the course of the program, 400 PM forged accelerators were delivered to the Army for testing. These parts were subjected to an extensive evaluation program that included firing tests at ambient and -60°F temperatures. Based on the satisfactory results of this testing program, the Army authorized the procurement of PM forgings for 26 components of the M85 machine gun under MIL-F-45961.

BENEFITS

This project demonstrated the suitability of PM forging in the manufacture of critical weapon components. Inclusion of this method in MIL-F-45961 provides the means for specifying that PM forged materials be used in the design of ordnance items.

IMPLEMENTATION

Presentation of a technical paper on this technical application has been made in-house and to members of the Tri-Services and Industry. This

project was completed too late in the production of the M85 machine gun for implementation in that program. However, the PM forging method was included and authorized under MIL-F-45961. Technical Report #AOD-TR-76-002 titled, "Closed Die Forging of Powder Metal Preforms" was issued in December 1976.

MORE INFORMATION

Additional information may be obtained by reviewing the Technical Report or by contacting Mr. J. Ronald Russell at AV 793-6586 or Commercial (309) 794-6586.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 674 7524 titled, "Ultra Hard Boride Coating to Reduce Tool Wear" was completed by the US Army Materials and Mechanics Research Center in June 1977 at a cost of $105,000.

BACKGROUND

The protection of metallic surfaces against erosion and chemical attack is a continuing problem both to the Army and the aircraft industry. There has been interest over a period of several years in using boron or various borides as a wear resistant surface or protecting medium. The reason for selecting boron and borides for this purpose is their possession of an unusual combination of properties, including high hardness, low density, resistance to chemical attack, good adherence, and a low coefficient of thermal expansion. There are a number of ways that boron and borides could be deposited onto metallic surfaces. The method used in this project was electrodeposition from a fused salt. The specific coating material was titanium diboride (TiB_2), which was applied to a variety of substrates as is shown in Figure 1.

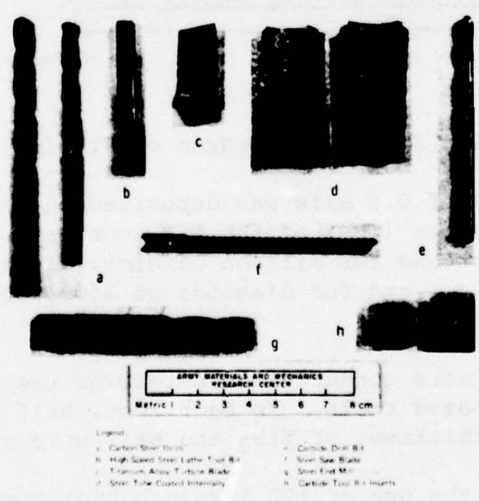


Figure 1 - Examples of Titanium Diboride Electrodeposited Coatings on Tools.

SUMMARY

This project was a cooperative effort of the Army Materials and Mechanics Research Center and the United Technology Research Center. The intent of this project was to provide a suitable hot salt bath electroplating furnace to deposit a TiB_2 coating on a statistically significant number of tools and to demonstrate the increased tool life and financial benefits of TiB_2 coated tools. Figure 2 is a schemetic of the electroplating furnace used to apply the coating.

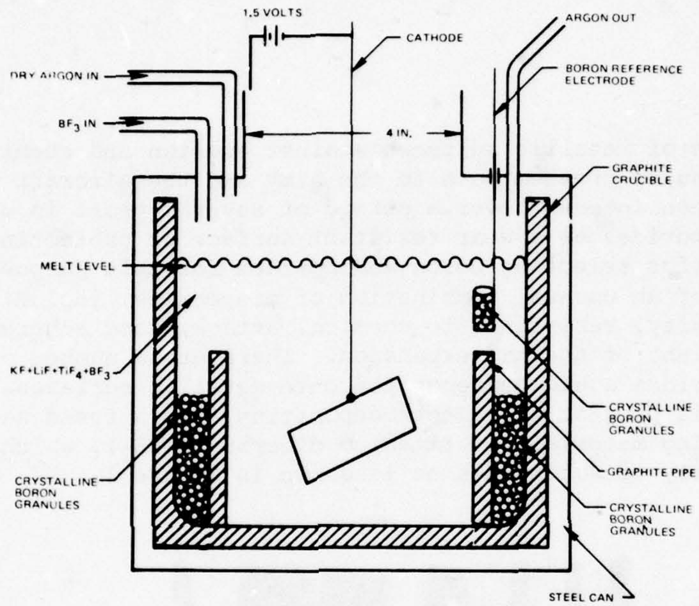


Figure 2 - Schematic Diagram of Plating Cell.

A coating thickness of 0.3 mils was deposited on the test tools. The Vickers hardness number (VHN) of the TiB_2 coating was 4060 $\pm$ 200. This can be compared to VHNs for silicon carbide, aluminum oxide, (both common grinding abrasives) and for diamonds of 2500, 3000, and 7000 respectively.

Various tool tests were conducted to determine the relative service life of coated and uncoated tools. In each test, half of the tools were coated with a 0.3 mil thickness of TiB_2 and half were uncoated.

The tests included the use of 120 1/4-inch high-speed steel drills on 4340 steel, 114 such drills on G-10 fiberglass, 56 5/8-inch square tungsten carbide turning inserts on 4340 steel, 32 such turning inserts on G-10 fiberglass, and 24 1/2-inch high-speed steel end mills used on G-10 fiberglass only.

Some findings of this effort were as follows:

a. The 0.3 mil thick TiB_2 coating plated on steel offered a tough, very hard, adherent layer, resistant to spalling and surface wear.

b. The coating improves the tool life of 1/4-inch high-speed drills used on fiberglass by a factor of 8.87.

c. The coating improves the tool life of 1/2-inch end mills used on fiberglass by a factor of 2.15.

d. The coating improves the tool life of 5/8-inch carbide inserts used on 4340 steel by 44 percent.

e. The coating did not improve the life of 5/8-inch carbide inserts used on fiberglass, nor the 1/4-inch high-speed twist drills used on 4340 steel. The loss in performance of the TiB_2 coated drills was at least partially due to metallurgical changes in the high-speed steel substrate which was caused by the high process temperature (1112°F - 1382°F) and which resulted in a loss of strength.

BENEFITS

Cost comparisons for selected fiberglass machining operations were presented in the Technical Report which showed savings in labor and tool cost to be 3% - 7% on drilling, 3% on turning, and 2.5% on end milling operations through the use of TiB_2 coated tools.

IMPLEMENTATION

A follow-on effort, MMT project 180 7302, has been funded which proposes to establish a production scale furnace for the coating of cutting tools to be used in machining fiberglass products. The methods of applying boride coatings for other components are being investigated in other related efforts such as projects 175 8017, "Erosion Resistant Leading Edge for Helicopter Rotor Blades", and 180 8116, "Erosion Resistant Coatings for Titanium Alloy Compressor Components".

MORE INFORMATION

Additional information on this project is available from Dr. William J. Croft, Applied Sciences Division, AMMRC, Watertown, MA 02172, AV 955-3454 or Commercial (617) 923-3455; or Technical Report #AMMRC TR77-17.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MUNITIONS

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 075 5071 titled, "Improvement of TECOM Production Test Methodology Engineering Measures" was completed in December 1977 by the US Army Test and Evaluation Command at a cost of $629,000.

BACKGROUND

This project is a continuing effort to update and develop new production testing technology consistent with advances in the manufacture of Army equipment. The problem is that the equipment testing facilities and capabilities must be continually advanced in relevant technology areas to keep pace with the Army equipment production testing requirement. Advancement must be made both by increasing capabilities of existing facilities and by developing new methodologies, techniques, and facilities.

SUMMARY

This project consisted of the following tasks: Dual Hardness Steel Ballistic Test Specification Refinement, Infrared Fuze Chronograph System Development, Improved Military Marine Equipment Testing Study, Acceptance Test Procedures, Improved Materiel Handling Test Method Development, Acceptance Test Procedures Validation, In-Bore Flash Radiography, Point Detonating Fuze Spotting Charge Evaluation, Infrared Fuze Chronograph System, Discarded Projectile Hardware Aerodynamics, Pollution Measuring/Detection, Trajectory Summit Exterior Ballastic Study, and Refrigeration Units Low Temperature Capabilities Study.

Of these tasks, all but one was completed. The Infrared Fuze Chronograph System was terminated. The following tasks are representative of the objective and results of the work accomplished by this project.

In-Bore Flash Radiography. The objective of this task was to determine x-ray film sensitivity and penetration capability of radiation from the 2.3-MV flash x-ray system. Various film/screen radiograph parameters were examined at various thicknesses of standard cannon tubes. Numerous radiographic films, fluorescent intensifying screens, and lead screens were evaluated to determine the optimal combination for producing the maximum penetration into a gun tube material (steel). All the films used were medical type, light sensitive. It was determined that exposing one

sheet of film sandwiched between a set of intensifying screens would allow up to 3.9 inches (9.9cm) of steel to be penetrated with a 5% contrast sensitivity. For multiple sheets of film sandwiched between a pair of intensifying screens, greater than five inches (12.7cm) of steel can be penetrated with 5% or better sensitivity.

Discarded Projectile Hardware Aerodynamics Study. The objective of this task was to determine the aerodynamics of discarded projectile parts; sabots, baseplates, spacer disks, safety pins, etc. These discarded projectile items are a potential safety hazard to personnel in the vicinity of the weapons being fired since the trajectories of these parts are not known. Discarded parts from projectiles in the current inventories were examined analytically and experimentally regarding flight distances.

Improved Military Marine Equipment Testing Study. The objective of this task was to identify improved Marine Equipment production testing techniques, facilities, and instrumentation. This entailed the review of state-of-the-art, existing testing methodologies, techniques, and facilities. Also, the optimum utility of the Aberdeen Proving Ground facilities were determined and upgrading proposals were formulated. Concepts for maximum use of data, simulation and accelerated testing were also presented.

BENEFITS

In general, the benefits realized by the Army from this project included improved production testing facilities, methodologies, techniques and data collection systems. These tasks resulted in improving testing accuracy and range safety. Specifically, the benefits derived from the three tasks cited herein are as follows:

In-Bore Flash Radiography. A flash radiographic technique with a 5% contrast sensitivity was developed to evaluate gun tubes.

Improved Military Marine Equipment Testing Study. A facilities plan for the anticipated increase of production testing requirement for Military Marine Equipment was established.

Discarded Projectile Hardware Aerodynamics Study. The firing range danger zone associated with fired projectiles with discarded parts was established.

IMPLEMENTATION

The results of these tasks have been implemented as follows:

In-Bore Flash Radiography Technique is currently being used to perform in-bore gun tube inspections.

Improved Military Marine Equipment Testing Study results have been used to formulate proposed MCA Construction projects to upgrade the APG Marine Equipment test facilities.

Discarded Projectiles Hardware Aerodynamic Study results were used to prepare range safety diagrams for safety control.

MORE INFORMATION

To obtain more information, contact the project officer, Mr. G.H. Shelton, AV 283-3677 or Commercial (301) 278-3677.

Summary Report was prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 576 3110 titled, "Engineering an Automated Switch Assembly Machine" was completed in September 1979 by the US Army Armament Materiel Readiness Command at a cost of $78,600.

BACKGROUND

Historically, the Army has not used inertial impact switches for non spin rounds. However, in recent years, these switches have demonstrated flight safety and impact reliability in large artillery and rocket fuzes. As a result, crush switches and piezoelectrics are being replaced by these inertial switches due to the lower cost, smaller size, greater sensitivity and reliability. Currently these switches are being produced manually at a rate of 50 switches per hour. The five year plan requirements calls for 12.4 million switches.

SUMMARY

The objective of this effort was to design an automated impact switch assembly machine using commercially available components. The machine will have the capability to automatically assemble M734, M732, M728, M735, M587, M724, M433, M438, and FMU-98 impact switches at a rate of 1200 per hour using one operator. The results of this effort produced an automated impact switch assembly machine design with a complete equipment procurement technical data package (TDP). The machine design included the capability to add an automatic test and packaging station at a later date.

BENEFITS

The benefit realized by the Army from this effort is an automated Impact Switch Assembly Machine design and equipment procurement Technical Data Package.

IMPLEMENTATION

This Automated Impact Switch Machine design and TDP is available for implementation. Currently, consideration is being given to using this machine in the production of M724 and M587 fuzes.

MORE INFORMATION

To obtain more information, contact the project officer, Mr. George Lucey, AV 290-2680 or Commercial (202) 282-2680.

Summary Report was prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology projects 571 4041 and 574 4041 titled, "Development of Automated Equipment for Assembly of Mortar Components" was completed by the US Army Armament Command in February 1976 at a cost of $260,000.

BACKGROUND

The equipment used to assemble mortar components is inefficient, uneconomical, and occasionally unreliable. High costs are also incurred by the need for production and inspection personnel. The objective of this program was to develop the engineering to modernize and automate the assembly of explosive components for both the 81mm and 60mm mortar ammunition. Specifically involved were the Ignition Cartridges XM299 and XM702 and the Propellant Increments XM195 and XM194. Also to be affected were the assembly and pack equipment and facility design conversion for production lines located at Milan and Lone Star AAP's.

SUMMARY

The first year effort was conducted in-house to establish the optimum sequence of operations for the automated equipment required to load, assemble and pack (LAP) the 60mm and 81mm Propelling Charges and Ignition Cartridges, see Figure 1. Product design problems and related type classification delays prevented contractual planning or action. Extensive effort was directed towards support of Kansas Army Ammunition Plant in another project for the automated assembly of the M374A2E1 Cartridge. See Figures 2 and 3 for line plan. This effort included safety tests related to the components and the high explosive (HE) filled shell and the design effort for the automated assembly of a complete round. Safety tests relative to lethal fragmentation conditions for various HE shell/machine combinations were conducted at Naval Civil Engineering Laboratory. The second year of funding was used to revise the planned sequence of operations and scopes of work as the result of propelling charge and ignition cartridge design changes. The propellant charge package design was changed from a cellulose nitrate container with a cotton bag filled with propellant to a felted nitrocellulose container filled directly with propellants. A portion of the sequence revision was due to new concepts in the automated inspection area of the LAP system. This made it a more complex and costly production system; however, production costs were offset by reduced requirements for manual labor.

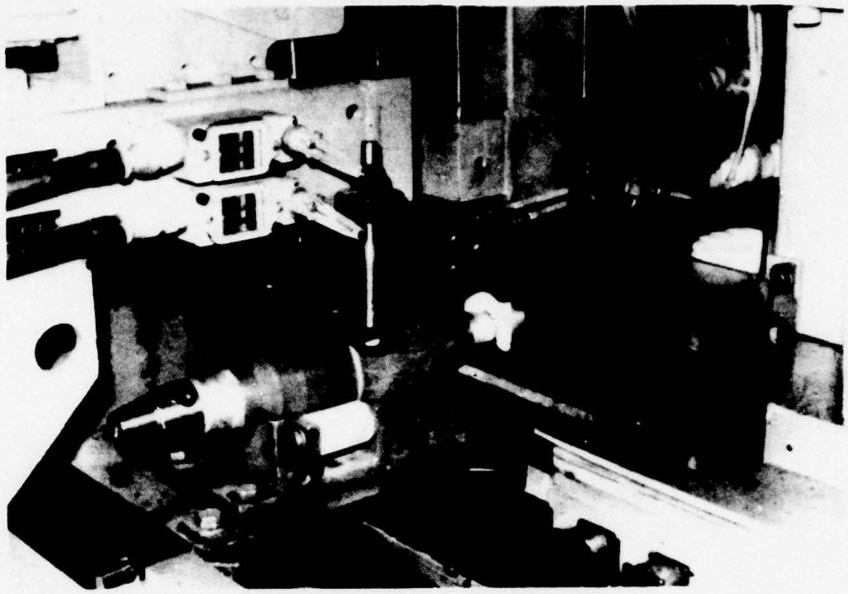


Figure 1 - Typical station for an M205 Propelling Charge Assembly.

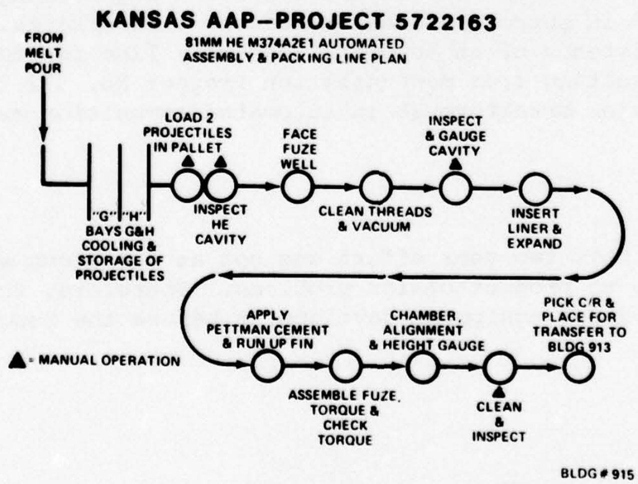


Figure 2 - 81MM HE M374A2E1 Automated Assembly and Packing Line Plan.

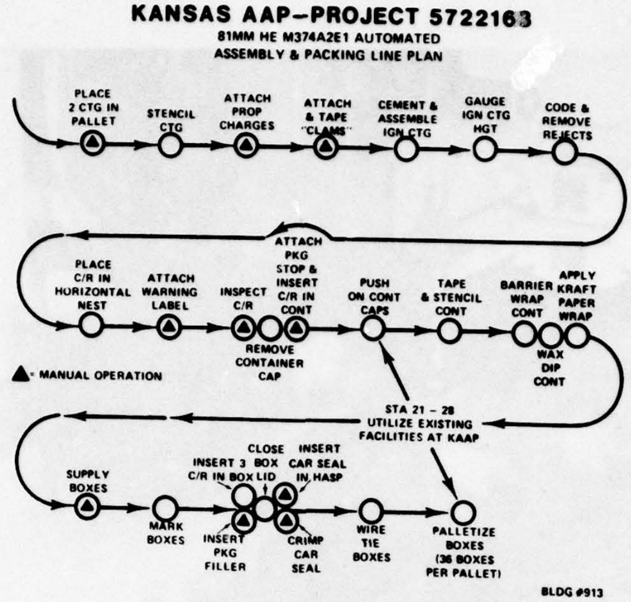


Figure 3 - Automated LAP Plan Continued

BENEFITS

Due to the product design problems, the project could not be completed as originally planned; however, the final plans and scope revisions emanating from this project were applicable to FY75 and FY76 equipment development efforts. Major benefits were realized for the engineering and testing efforts expended in support of KAAP automated line efforts. This is borne out by the existence of an automated assembly line for the 81MM M374A3 Cartridge resulting from modernization Project No. 572 2163. This line represents a major breakthrough in automated ammunition manufacture.

IMPLEMENTATION

The progress of this two year effort was not as far along as was originally planned due to product design problems. Therefore, follow-on efforts were required for equipment development before the results could be implemented.

MORE INFORMATION

Additional information of these projects is available from Mr. O.E. Anderson, ARRADCOM, AV 880-6279 or Commercial (201) 328-6279.

Summary Report was prepared by Robert S. Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 573 4171 titled, "Investigation of Parameters Affecting the Nitrolysis of Hexamine" was completed in March 1977 by the US Army Armament Research and Development Command at a cost of $185,000.

BACKGROUND

This project is a continuation of the investigations initiated to determine the parameters affecting the RDX/HMX process and to establish the optimum operating conditions. The FY71 and FY72 projects involved the use of micro and mini pilot scale equipment to evaluate various process modification to the batch and continuous process for producing HHX. Follow-on efforts at bench level were planned in order to scale up the previous work before proceeding to process modifications on the actual production line at Holston AAP.

SUMMARY

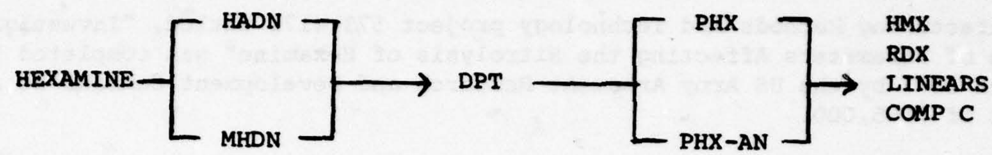
The primary objective of this study was to develop chemical and process data upon which to base improvements in HMX manufacture. This was achieved by performing laboratory-scale studies of the nitrolysis using batch processes. The approach was to verify the reaction path, determine the origin of yield losses and recommend process changes. In addition, key nitramine intermediates and by-products were synthesized in support of the FY71 and FY72 contract effort by Illinois Institute of Technology Research Institute (IITRI).

The major apparatus consisted of batch nitrating equipment and a chemical feed system. The nitrating equipment consisted of three to ten liter stirred cylindrical vessels made of stainless steel and pyrex glass. The bottoms were jacketed for heating or cooling. They contained a turbine type agitator driven by a variable speed air motor. The feed systems were calibrated glass burettes fitted with stopcocks to meter individual reactants. Each burette was calibrated to deliver proportionate increments.

Significant advances were made in the application of instrumental methods for following the progress of the reaction. Gas-liquid chromatography (GLC), liquid-liquid chromatography (LLC), or nuclear magnetic resonance spectroscopy (NMR) provided capabilities to handle nitramine

solids or reaction slurries for instantaneous measurement of reactant consumption or nitramine products.

The reaction path for HMX was confirmed by studies of the intermediate compounds. The main reactions leading to HMX were determined as:



where,

HADN - Hexamine dinitrate
MHDN - Methylhexaminedinitrate
DPT - Dinitropentamethylenetetramine
PHX - 1-Acetomethyl-3,5,7 trinitro-1,3,5,7-tetrazacyclooctane
PHX-AN - 1-N-Nitromethylene-3,5,7-trintrocyclotetramethylenetetramine
LINEARS - straight chain nitramine compounds
COMPOUND C - An unidentified by-product nitramine

This reaction path was observed in both the laboratory and production-scale operations and holds over a wide variation in parameters.

It was found that HMX yields were low in standard nitrolysis for the following reasons: a) major yield loses occur because of formation of RDX, linear esters and Compound C, b) HADN decomposes to yield MHDN which reflects a loss of potential methylene, c) PHX and PHX-AN both decompose to by-products such as Compund C, and d) PHX-AN converts only partially to HMX.

The parameters associated with the conversion of synthesized intermediates to HMX were surveyed at each step in the reaction sequence. During the first addition, the DPT yield was not affected by reducing the acetic anhydride by 53%. In the second addition, PHX was very sensitive to nitrolysis conditions, and a higher reaction temperature would increase conversion to a high yield of HMX. Compound C was found to be derived principally from PHX-AN.

The following recommendations were developed from the preceeding laboratory studies:

a. The special instrumental methods of analysis - GLS, LLC, and NMR - used in these studies should be more fully explored and applied in the critical areas of the reaction.

b. The merits of MHDN as an HMX precursor should be established.

c. The role of ammonium nitrate in the nitrolysis reaction should be examined in depth since it plays a key role in depressing side reactions to form Compound C and linears.

d. Since heat removal capacity is a deterent to throughput rates, attention should be given to redistributing the heat load by reaction parameters or by engineering design of the containment vessels.

BENEFITS

These studies verified the reaction path for the nitrolysis to HMX and provided process data needed for scaling-up the prccess improvments for pilot scale evaluation.

IMPLEMENTATION

The process improvements indicated by this effort will be evaluated on a pilot scale in follow-on MMT project 578 4252.

MORE INFORMATION

Additional information can be obtained by contacting the project officer, Mr. S. Dollman, AV 880-2160 or Commercial (201) 328-2160.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT - 302)

Manufacturing Methods and Technology project 571 4201 titled, "Safety Engineering in Support of Ammunition Plants" was completed by the US Army Armament Materiel Readiness Command in August 1974 at a cost of $470,578.

BACKGROUND

Procedures contained in the published regulatory manual TM5-1300 for "Structures to Prevent the Effects of Accidental Explosions", prepared under the direction of Picatinny Arsenal, have been used to design structures for ammunition plants and facilities. However, some procedures have been found to be limited in scope. These limitations may result in over--design which would lead to increased construction costs. This project was undertaken to broaden the overall scope of TM5-1300 manual to provide safer, more economical and realistic criteria for modification of existing and new ammunition manufacturing and storage facilities. Prior effort in this area was sponsored by the Armed Services Explosives Safety Board (ASESB) and resulted in the publication of TM5-1300.

SUMMARY

The purpose of this project was to support the Army's Modernization and Expansion Program for maximum safety of personnel and equipment against accidental explosions and their propagation. The overall objective of this project was to develop new design criteria which could be integrated into the existing regulatory manual TM5-1300 to enhance the economical construction of both functional and safe ammunition manufacturing facilities. There were five major task areas of accomplishments: a) TNT equivalency of black powder tests, b) establishment of safe separation distances and/or shielding between 155mm (MT) Comp B projectiles/TNT boxes on a conveyor during assembly, c) evaluation of leakage pressure, venting and frangibility effects resulting from accidental detonation in a cubicle type structure, d) reviews of four Army ammunition plant facilities, and e) concept design studies at five Army ammunition plant facilities.

Project accomplishments for this effort were too numerous to include in this report. One example selected to demonstrate typical accomplishments was the "Eight-Inch Separation Propagation Tests for Cartridge, 81mm, HE, M374A2E1, and Projectile 81mm, HE, M374".

In these tests, a transfer pallet incorporating a 12-inch center-to-center spacing, allowing 8.8 inches spacing between 81mm projectiles loaded with Composition B, was designed for use in an automated system to assemble and pack the M374A2E1 81mm HE cartridge at the Kansas Army Ammunition Plant. These tests had two objectives. The first was to verify that the designed transfer pallet incorporating an 8.8 inch space between projectiles (12 inch center-to-center spacing) would prevent explosive propagation when 2" x 4" x 14" aluminum interruption bars assembled one inch above the pallet base were used between projectiles. The second objective of the test program was to verify that the same transfer pallet with the addition of lexan shields between propelling charges would contain burning of the propellant charge when complete rounds are being carried.

Each test setup for both phases consisted of a donor projectile, two acceptor projectiles, supporting pallets, and aluminum separator bars.

The first phase tests consisted of 44 tests of the 81mm, HE, and M374A2E1 projectiles loaded with Composition B, with simulated work station tooling attached. These tests verified that propagation of an explosive incident would not occur.

The second phase consisted of 25 tests of the same projectiles as complete rounds with XM195 propelling charges attached. Plexiglass shields were attached to the simulated pallet to contain ignition flash. These tests demonstrated that six inch high lexan shields had to be attached to the pallet to prevent propagation of propellant charge ignition.

Both phases of these tests confirmed that under the tested conditions, propagation of an explosive event would not occur.

BENEFITS

Test results of the 81mm projectile example discussed herein provided safe spacing criteria for designing automated transfer pallets used in assembly of projectiles.

The total 571 4201 project work resulted in data that can be used to improve safety and economy in ammunition handling equipment and facilities design.

IMPLEMENTATION

Results of this project are being incorporated in safety design manuals TM5-1300 and AMCR 385-100. Results were applied to support the

"Automated Assembly and Packout of Cartridge, 81mm, HE, 374A2E1" at the Kansas Army Ammunition Plant (KAAP).

MORE INFORMATION

Additional information on this project is available from Mr. J.R. Marsicovete, ARRADCOM, AV 880-3906 or Commercial (201) 328-3906.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 572 4201 titled, "Safety Engineering in Support of Ammunition Plants" was completed by the US Army Armament Materiel Readiness Command in November 1974 at a cost of $979,885.

BACKGROUND

Procedures contained in the published regulatory manual TM5-1300 for "Structures to Prevent the Effects of Accidental Explosions" prepared under the direction of Picatinny Arsenal have been used to design structures for ammunition plants and facilities. However, some procedures have been found to be limited in scope. These limitations may result in over-design which would lead to increased construction costs. This project was undertaken to broaden the overall scope of TM5-1300 manual to provide safer, more economical and realistic criteria for modification of existing and new ammunition manufacturing and storage facilities. Prior effort in this area was sponsored by the Armed Services Explosives Safety Board (ASESB) and resulted in the publication of TM5-1300. Prior effort also involved project 571 4201 titled, "Safety Engineering in Support of Ammunition Plants."

SUMMARY

The purpose of this project was to support the Army's Modernization and Expansion Program for maximum safety of personnel and equipment against accidental explosions and their propagation. The overall objective of this project was to develop design criteria which could be integrated into the existing regulatory manual TM5-1300 to enhance the economical construction of both functional and safe ammunition manufacturing facilities. There were six major areas of accomplishments: a) TNT equivalency tests, b) establishment of safe separation distances of explosive materials on a conveyor, c) evaluation of leakage pressures, venting and frangibility effects resulting from detonation of HE charge within a cubicle, d) structure response study to limit blast effects, e) preparation of supplements to TM5-1300 and AMCR 385-100, and f) review and evaluation of several facilities design.

Project accomplishments for this effort were too numerous to include in this report. As a result, only one accomplishment is described here

to demonstrate typical accomplishments. The example discussed here is "TNT Equivalence of N-5 Slurry and Paste."

The objective of this project was to experimentally determine the TNT equivalencies of a premix N-5 slurry containing Nitroglycerin (NG), Nitrocellulose (NC), Diethylphthalate (DEP), and 88% process water. In addition, TNT equivalencies were also determined for N-5 paste containing 30% moisture, and N-5 paste containing 10% moisture. The safe separation between drums of N-5 paste (10% moisture) was also evaluated. The N-5 slurry with 88% process water was tested in both confined and unconfined configurations. The two N-5 paste materials were only tested in unconfined configurations. Twenty-five tests were performed to accomplish this objective.

Eleven tests were conducted with the N-5 slurry which did not ignite using C4 boosters weighing 4 to 48 ounces. The charge weights were varied from 11.5 lbs to 400 lbs.

Two tests were conducted with N-5 paste with 30% moisture. The N-5 paste was ignited only once and that was with a 48 ounce C4 booster. The resulting pressure and impulse TNT equivalencies were four and two percent respectively.

Eight tests were conducted with N-5 paste with 10% moisture. The N-5 paste was detonated when a 5.5 gram or larger tetryl booster was used. The resulting pressure and impulse TNT equivalencies were 95 and 70 percent respectively. This material only ignited with electric squibs or Black Powder boosters.

Four sympathetic detonation tests were carried out on N-5 paste with 10% moisture, to bracket separation distances into three regions. They are detonation, burn, and no reaction regions. The results indicated sympathetic detonation occurs at scaled distances of less than 0.5, the sympathetic burn region occurs between scaled distances of 0.5 and 7, and no ignition occurs beyond scaled distances of 7.

In the summary of the "TNT Equivalence of N-5 Slurry and Paste" tests, the following conclusions were reached:

a. The N-5 slurry (88% process water) is a very insensitive in-process material. All attempts to ignite this material failed.

b. The N-5 paste (30% moisture) has a very low reaction intensity level when ignited with a large booster.

c. The N-5 paste (10% moisture) is very sensitive to shock loading and shows a very high reaction intensity level and TNT equivalency when detonated. It was demonstrated that this material will detonate in an unconfined configuration when stimulated with a high explosive booster.

BENEFITS

Results of TNT equivalency tests, from this project, were used to redesign two facility projects. In essence, it was learned that the explosive force of the materials that were to be used in the new facilities was not as great as once believed. Therefore, thickness of concrete construction could be reduced and it was in this area that most of the cost savings can be realized.

Results of this project places safety requirements on a cost effective basis through the incorporation of test results in safety design manuals TM5-1300 and AMCR 385-100.

IMPLEMENTATION

Information generated from this project is being applied to new plant construction and modernization and evaluation of current ammunition facilities to improve safety and economy.

MORE INFORMATION

Additional information on this project is available from Mr. J.R. Marsicovete, ARRADCOM, AV 880-3906 or Commercial (201) 328-3906.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 573 4201 titled, "Safety Engineering in Support of Ammunition Plants" was completed by the US Army Armament Materiel Readiness Command in November 1974 at a cost of $1,168,111.

BACKGROUND

Procedures found in the published regulatory manual TM5-1300 for "Structures to Prevent the Effects of Accidental Explosions" prepared under the direction of Picatinny Arsenal have been used to design structures for ammunition plants and facilities. However, some procedures have been found to be limited in scope. These limitations may result in over-design which would lead to increased construction costs. This project was undertaken to broaden the overall scope of TM5-1300 manual to provide safer, more economical and realistic criteria for modification of existing and new ammunition manufacturing and storage facilities. Prior effort in this area was sponsored by the Armed Services Explosives Safety Board (ASESB) and resulted in the publication of TM5-1300. Prior effort also involved projects 571 4201 and 572 4201 titled, "Safety Engineering in Support of Ammunition Plants".

SUMMARY

The purpose of this project was to support the Army's Modernization and Expansion Program for maximum safety of personnel and equipment against accidental explosions and their propagation. The overall objective of this project was to develop design criteria which could be integrated into existing regulatory manual TM5-1300 to enhance the economical construction of both functional and safe ammunition manufacturing facilities. The seven major areas of accomplishments were: a) TNT equivalency tests, b) sensitivity studies, c) weapons effects studies, d) structural response studies, e) preparation of supplements to TM5-1300 and AMCR 385-100, f) assistance in preparation of concept studies, and g) special studies on critical and safe heights of M1 propellant.

Project accomplishments for this effort were too numerous to include in this report. One example selected to demonstrate typical accomplishments was the "Explosive Sensitivity of 155mm Projectile, RDX Slurry and Black Powder to Impact by Concrete Fragments". In these sensitivity tests, 70 experiments were run.

Twenty experiments were made in which 155mm Composition B filled projectiles were impacted with concrete fragments. The velocity of the concrete fragments varied from a minimum of 350 fps to a maximum of 1170 fps and their weight ranged from 55 to 480 pounds. All concrete fragments were 12 inches in diameter and from six inches to five feet in length. The experiments resulted in some deformation of the projectiles casing but no reaction of the Composition B contained in the projectiles occured.

Fourteen experiments in which RDX slurry was impacted with concrete fragments were performed. These fragments were the same sizes and varying velocities as those used in the previous twenty experiments. The charge weight of the RDX slurry in these experiments ranged from 15 to 35.5 pounds. No reaction of the RDX slurry resulted from these experiments.

Using 30 caliber bullets, 16 shots were fired from a distance of 300 feet into RDX slurry. Ten of these shots were fired into a plywood box containing 13 pounds of RDX slurry and six shots were fired into a steel canister containing nine pounds of RDX slurry. Bullets used consisted of a mix of both armor piercing and copper ball bullets. The RDX slurry did not react to impact by the bullets.

Twenty concrete fragment impact experiments were carried out against single 25 pound charges of Black Powder packed in their shipping containers. The concrete fragments were 12 inches in diamter, ranged in weight from 55 to 480 pounds and had a velocity at the target of 100 to 1055 fps. Both reactions and no reactions were produced in these experiments. From the results of these twenty experiments, a projectile mass-velocity profile indicating the combination under which reaction of Black Powder to impact by concrete fragment could be expected was established.

BENEFITS

Test results of the explosive sensitivity of 155mm projectile, RDX slurry and Black Powder subjected to impact by concrete fragments provided simulation tests of wall fragments after failure. The information gained here will serve to establish criteria whereby the safety level of walls in existing facilities can be analyzed and design requirements can be established for safe operation in newly planned facilities.

The total project work will result in improved safety and economy in ammunition handling equipment and facilities design.

IMPLEMENTATION

Results of this project are being incorporated in safety design manuals TM5-1300 and AMCR 385-100. Several technical reports were prepared for this effort and distributed to major subordinate commands, installations and activities within DARCOM.

MORE INFORMATION

Additional information on this project is available from Mr. J.R. Marsicovete, ARRADCOM, AV 880-3906 or Commercial (201) 328-3906.

Significant technical reports published as a result of this project are listed below.

TR 4622: 55# TNT and Comp B boxes.
TR 4623: RDX & HMX Slurry.
TR 4594: Explosive sensitivity of 155mm Projectiles, RDX Slurry and Black Powder to Impact by concrete fragments.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT - 302)

Manufacturing Methods and Technology project 574 4201 titled, "Safety Engineering in Support of Ammunition Plants" was completed by the US Army Armament Materiel Readiness Command in December 1978 at a cost of $1,327,262.

BACKGROUND

Procedures contained in the published regulatory manual TM5-1300 for "Structures to Prevent the Effects of Accidental Explosions", prepared under the direction of Picatinny Arsenal, have been used to design structures for ammunition plants and facilities. However, some procedures have been found to be limited in scope. These limitations may result in either over-design, which would lead to increased construction costs, or under-design, which may not provide full safety protections. This project was undertaken to broaden the overall scope of TM5-1300 manual to provide safer, more economical and realistic criteria for modification of existing and new ammunition manufacturing and storage facilities. Prior effort in this area was sponsored by the Armed Services Explosives Safety Board (ASESB) and resulted in the publication of TM5-1300. Other prior efforts included projects 571 4201, 572 4201, and 573 4201 titled, "Safety Engineering in Support of Ammunition Plants".

SUMMARY

The purpose of this project was to support the Army's Modernization and Expansion Program for maximum safety of personnel and equipment against accidental explosions and their propagation. The overall objective of this project was to develop new design criteria which could be integrated into the existing regulatory manual TM5-1300 to enhance the economical construction of both functional and safe ammunition manufacturing facilities. There were five major task areas of accomplishments: a) TNT equivalency tests, b) sensitivity studies, c) blast effects and loadings, d) structural response and design, and e) hazard classification.

Project accomplishments for this effort were too numerous to include in this report. One example selected to demonstrate typical accomplishments was the "Blast Capacity Evaluation of Belowground Structures".

In these tests, a series of ten explosions were performed on one-third scale structures. These tests evaluated the capacity of below-ground reinforced concrete cells to resist the effects of internal explosions. Tests were run on two different cells. The cells were 2.44m

(8 feet) cubes consisting of four concrete walls, a concrete apron, a floor slab and an open roof. The top of the structures were at ground level. The apron was removed prior to performing the last test on each structure. Eight tests were performed on one of the models, while the other structure cell was subjected to the effects of only two explosions. The quantities of explosives used in the first three tests (Cell No. 1) were small, 2.7 kg (6 lbs) and less. Tests 4, 5, 6, 7, and 9 of Cell No. 1 used explosive quantities of 11.2, 19.5, 28.8, 36.9, and 68.0 kg (25, 43, 63, 81, and 150 lbs) respectively. Tests 8 and 10 were performed on Cell No. 2 and utilized explosive quantities of 86.7 and 113.4 kg (191 and 250 lbs) respectively.

The cell used in the first seven tests and test 9 survived the combined effects of the eight explosions; on the other hand, the second cell failed during the second test performed on it. Based upon these results, it is estimated that the maximum blast-resistant capacity of the full-scale structures of the configuration tested is in the order of 2,700 to 3,600 kg (6,000 to 8,000 lbs) of H.E.

The results of these tests indicate that when subjected to the effects of an internal explosion, belowground structures with no roof will have an upper explosive limit beyond which the structure will fail and thereby become a source of secondary fragments. This failure limit is less than that which was considered in most past facility designs. Previously, most past facility designs only considered the requirements for conventional loading (soil pressures) without giving consideration to blast effects associated with an explosion. An example of this underdesign was determined in the complete failure of the belowground portion of building 9502 at Radford AAP during an accidental explosion.

BENEFITS

This project produced new and experimentally proven test data that was not previously available for designing underground structures. Applying this test data as design criteria will assure the design of much safer buildings that are used in the manufacture and handling of explosives and propellants.

IMPLEMENTATION

Results of this project have been implemented in the designing of facilities at Lone Star AAP. Several technical reports were prepared during this effort and distributed to major subordinate commands, installations and activities within DARCOM. Test results are being submitted through necessary channels for inclusion in appropriate regulations and manuals, TM5-1300 and AMCR 385-100.

MORE INFORMATION

Additional information on this project is available from Mr. J.R. Marsicovete, ARRADCOM, AV 880-3906 or Commercial (201) 328-3906.

Numerous technical and contractor reports published as a result of this project are available.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 575 4201 titled, "Safety Engineering in Support of Ammunition Plants" was completed by the US Army Armament Materiel Readiness Command in June 1978 at a cost of $1,000,000.

BACKGROUND

Procedures contained in the published regulatory manual TM5-1300 for "Structures to Prevent the Effects of Accidental Explosions", prepared under the direction of Picatinny Arsenal, have been used to design structures for ammunition plants and facilities. However, some procedures have been found to be limited in scope. These limitations may result in over-design which would lead to increased construction costs. This project was undertaken to broaden the overall scope of TM5-1300 manual to provide safer, more economical and realistic criteria for modification of existing and new ammunition manufacturing and storage facilities. Prior effort in this area was sponsored by the Armed Services Explosives Safety Board (ASESB) and resulted in the publication of TM5-1300. Other prior efforts included projects 571 4201, 572 4201, 573 4201, and 574 4201.

SUMMARY

The purpose of this project was to support the Army's Modernization and Expansion Program for maximum safety of personnel and equipment against accidental explosions and their propagation. The overall objective of this project was to develop information and criteria for design of a complete LAP and explosive manufacturing facility. The information will broaden the scopes of safety manuals TM5-1300 and AMCR 385-100. There were five major task areas of accomplishments: a) TNT equivalency tests, b) sensitivity studies, c) blast effects and loadings, d) structural response and design, and e) hazard classification and special design studies.

Project accomplishments for this effort were too numerous to include in this report. One example selected to demonstrate typical accomplishments was the "Critical Depth Tests of Composition B Flake".

These tests were performed to determine ways to safely convey Composition B Flake between an Automatic Inspection Building and Melt/Pour Buildings at Lone Star Army Ammunition Plant. Four series of tests were performed.

The first series of 16 tests were performed using a commercially available rubber belt conveyor and simulated conveyors fabricated from wood. Conveyor lengths were 1.52m (5 ft), 2.44m (8 ft), 3.05m (10 ft), and 4.88m (16 ft). The depth of Composition B Flake was varied from 25mm (1 in) to 50mm (2 in) in increments of 6.35mm (1/4 in). Two widths of the conveyor used were 0.29m (11-1/4 in) and 0.44m (17-1/2 in). Detonation tests indicated that 0.29m (11-1/4 in) conveyor was more suitable from the safety standpoint than the 0.44m (17-1/2 in) wide conveyor for the same depth of explosive.

The second series consisted of 18 tests and used 0.29m (11-1/4 in) and 0.43m (17 in) wide simulated wooden conveyors. Rubber cleats which were 76mm (3 in) high by 6.3mm (1/4 in) thick were glued or stapled into wooden conveyors at various spacings. High order detonation propagations made it clear that the cleats cannot be relied upon for prevention of propagation of explosions. This resulted in the air-gap concept being tested. Air-space was used to separate two adjoining batches of Composition B Flake, each batch weighing approximately 25kg (55 lbs). All tests with air-gaps ranging from 0.075m (3 in) to 0.61m (24 in) were successful.

The third series of tests was directed at finding a practical means to use the air-gap concept for conveyors. Two different kinds of spacers, one round and one square, were devised and tested in 21 tests. Seven of these tests used rubber belt conveyors. All tests proved successful using a 0.1m (4 in) air-gap.

The fourth series of 20 tests was confirmatory in nature and was performed using commercially available corrugated rubber belt conveyors. The clear separation between the explosives in two adjacent troughs of the conveyor was maintained at 51mm (2 in). Some tests used the two-acceptor arrangements, that is, one acceptor on each side of the donor, while one acceptor was used in the remaining tests. There was no detonation propagation in any of the 32 acceptors employed. Test results provide statistical data for predicting reliabilities for non-occurence of propagation of detonations at given confidence levels. The test results concluded that a 38mm (1-1/2 in) depth of explosive on a 0.38m (15 in) commercially available corrugated rubber belt conveyor, as used in these tests, or a 0.1m (4in) air-gap between explosives in two adjoining batches of explosives will prevent propagation of explosion along the conveyor.

BENEFITS

Test results of the example described here, "Critical Depth tests of Composition B Flake" have been applied to safely convey Composition B Flake on Conveyors between Automatic Inspection Building and Melt/Pour Buildings of the 105mm Load-Assemble-Pack (LAP) line at Lone Star Army Ammunition Plant, Texarkana, Texas.

The total project work resulted in improved safety and economy in ammunition handling equipment and facilities design.

IMPLEMENTATION

The results of this project have been implemented in the design of new facilities at Lone Star AAP. Several technical reports were prepared for this effort and distributed to major subordinate commands, installations, and activities within DARCOM. Test results are being submitted for incorporation into safety design manuals TM5-1300 and AMCR 385-100.

MORE INFORMATION

Additional information on this project is available from Mr. J.R. Marsicovete, ARRADCOM, AV 880-3906 or Commercial (201) 328-3906.

Significant technical and contractor reports published as a result of this project are listed here.

PA TR 4901 - Blast Parameters of M26E1 Propellant.
ARLCD-CR-7703 - Blast Parameters of BS-NACO Propellants.
ARLCD-CR-77012 - Determination of the Effects of Shielded Tote Bins on the Safe Separation of 168 pounds of Comp A7 Explosive.
PA TR 5014 - Critical Depth Tests of Comp B Flake.
PA TR 4837 - Design of Steel Structures to Resist the Effects of HE Explosions.
PA TR 4838 - Design Charts for Cold-Formed Steel Panels and Wide Flange Beams Subjected to Blast Loads.
PA TR 4995 - Ground Shock Effects from Accidental Explosions.
PA TR 5020 - Explosive Tests for Establishing the Hazard Classification for MISP/105mm Propellant in the Automated Single Base Finishing Operations.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT - 302)

Manufacturing Methods and Technology project 575 4277 titled, "New DADN Processes for HMX Manufacture" was completed by the US Army Research and Development Command in June 1977 at a cost of $417,000.

BACKGROUND

The compound HMX is an important component in high energy explosives and is finding an increasing demand for both gun and rocket propellants. Presently, the only production source for HMX is the Bachmann process using production lines designed primarily for the manufacture of RDX. Unfortunately when HMX is produced, RDX production is reduced and the resulting HMX production rate is less than that of the RDX and costs more per pound than RDX. Therefore, alternate methods which could produce HMX without the conflict with RDX would be highly desirable. Alternate processes for the production of HMX were investigated by the Energetic Materials Division of ARRADCOM during the period of 1971 to 1975. Three processes, the "TAT Process", the "DANNO Process", and the "DADN Process" were developed and studied both in-house and at the University of Idaho. As a result of the research studies, the DADN Process was selected as the most promising process for further pilot studies.

SUMMARY

The objective of this effort was to evaluate by bench scale and pilot plant operations the production of HMX by the DADN process. The approach taken was to demonstrate, characterize, and optimize the DADN process and gather sufficient engineering data and experience to support the design of a full scale prototype production facility.

The DADN process is basically a three-step synthesis. Initially, hexamine is reacted with acetic anhydride and ammonium acetate to form diactyl pentamethylenetetramine (DAPT). A mixture of nitric and sulfuric acid is then added to DAPT to convert it to 1, 5-diacetyl-3, 7-dinitro-1,3,4,7-tetroazacyclooctane (DADN). This product is then nitrated with polyphosphoric acid and nitric acid to produce crude HMX.

Under this program, studies on the three-step DADN process were conducted at three locations. In-house studies at ARRADCOM covered laboratory efforts and cost analysis of the entire process. Los Alamos Scientific Laboratory (LASL) conducted laboratory and pilot studies of the

first two steps. At the United Technology Center (UTC), the application of the inert carrier (heptane) process to all three steps of the DADN process was investigated.

At ARRADCOM, the laboratory scale studies resulted in the successful preparation of 30 gram batches of HMX by the DADN process with separation and recycle of polyphosphoric acid, nitric acid, and acetic acid formed during nitrolysis. A cost analysis showed that the DADN process compared favorably with the Bachmann process, as operated at Holston AAP for production of crude HMX. It was pointed out that the DADN process would provide cheaper HMX if further improvements were realized by the use of 93% sulfuric acid in the second step and the reduction of reaction time in the third step. However, two major obstacles prevented the implementation of this process. They were the need of a radically new facility to produce HMX in lieu of the present Bachmann Process which produces either RDX or HMX and the recycle of four separate acids; namely, nitric, acetic, sulfuric, and polyphosphoric acids (PPA). The recycle and reconcentration of PPA to 83% P_2O_5 has not been accomplished commercially and based on data gathered from experts in the field, it may not be economically feasible. However, based upon laboratory results, vacuum concentration appeared to be possible.

LASL investigated on a pilot scale (13.6 lb/hr) the continuous preparation of DADN via DAPT from hexamine. This task was successfully completed and an overall conversion rate of 95% was demonstrated for the nitrolysis of hexamine to DADN. Based upon the economic evaluation performed, LASL was asked to investigate the use of 93% H_2SO_4 in lieu of 98% acid. It was also confirmed by LASL that 93% sulfuric acid could be utilized in the nitrolysis of DAPT to DADN with no loss in yield. In an attempt to completely eliminate the use of sulfuric acid, the preparation of a different intermediate compound, namely, DANNO was investigated. Based upon the data generated, it was determined that the DANNO process offered no advantages over the DADN process. On the contrary, the DANNO approach required increased nitrolysis times, excessive quenching, and generally resulted in lower yields, all of which negate the advantages gained from elimination of the sulfuric acid required in the DADN process.

A twofold program was conducted by UTC. The first phase consisted in the investigation of an inert carrier for the HMX via DADN process. Thirty-five pounds of DADN were produced in the pilot plant. The runs at the pilot plant produced HMX at a rate of 3.5 pounds per hour and 8.5 pounds per hour with yields of 60% and 80% respectively. These yields were 20% lower than those produced in the laboratory at ARRADCOM and LASL. Therefore, there was no indication that the use of an inert carrier was beneficial.

The second phase of the UT program was to investigate the use of solvent and non-solvent recrystallization to produce coarse HMX. This phase, as designed, was not successful. However, an alternate method to produce fine particle (5M) HMX was established. This process, in principle, is similar to the rapid quenching or aspirator methods utilized to shock HMX or RDX from solution.

The total effort conducted indicated that the DADN process did not appear to have a significant economic advantage over the improved Bachmann process at this time. However, based on the success of the pilot plant studies at LASL and the logistic advantage, further work was recommended. The logistic advantage was the fact that the intermediate products formed, DAPT and DADN, were non-explosive and could be produced at sites anywhere in continental North America. The future work recommended included additional pilot studies on the third step and emphasis on the reconcentration of the spent polyphosphoric acid.

BENEFITS

An alternative method, the DADN process for producing HMX, was demonstrated successfully at a pilot plant level for the first two steps of the reaction.

IMPLEMENTATION

There are no plans to pursue this process further since it offers no economic advantages over the current improved Bachmann process.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. R. Motto, AV 880-3717 or Commerical (201) 328-3717.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 576 4288 titled, "Explosive Safe Separation and Sensitivity Criteria" was completed by the US Army Armament Research and Development Command in September 1978 at a cost of $592,814.

BACKGROUND

A multi-year MMT effort (57X 4201) commenced in FY71 and was titled, "Safety Engineering in support of Ammunition Plants". Applications of the data developed under project 57X 4201 resulted in establishing safe separation distances for several explosive in-process materials and explosive end items. Additional exploratory tests with explosive end items and fragment impact tests (against molten explosives) indicated major problem areas still faced GOCO Plant Modernization Programs. Hence, additional testing was imperative for providing additional information for proper and safe designs to modernize facilities.

SUMMARY

The objective of this project was to develop new data to upgrade safety criteria for munition processes and facilities in support of Army's Modernization and Expansion Program. The data developed from this project was to cost effectively provide maximum safety to personnel and equipment against explosion propagation. Three major areas of data development were evaluated: a) the safe separation of explosive end items and in-process materials at various stages of their manufacturing process, b) the critical and safe depths of bulk explosives on conveyor systems, and c) the sensitivity of explosives at various stages of their manufacturing process to impact from primary and secondary fragments.

Project accomplishments for this effort were too numerous to include in this report. One example selected to demonstrate typical accomplishments was the "Determination of Minimum Non-Propagation Distance of 81mm M374A1 Projectiles".

In the tests performed for this example, Load-Assemble-Pack plant conditions were simulated to determine minimum safe distances between projectiles containing 0.981 kilograms (2.163 pounds) of explosive Composition B. The projectiles were tested for minimum non-propagative clear spacing between single projectiles and between pallets containing 72 projectiles each; see Figure 1.

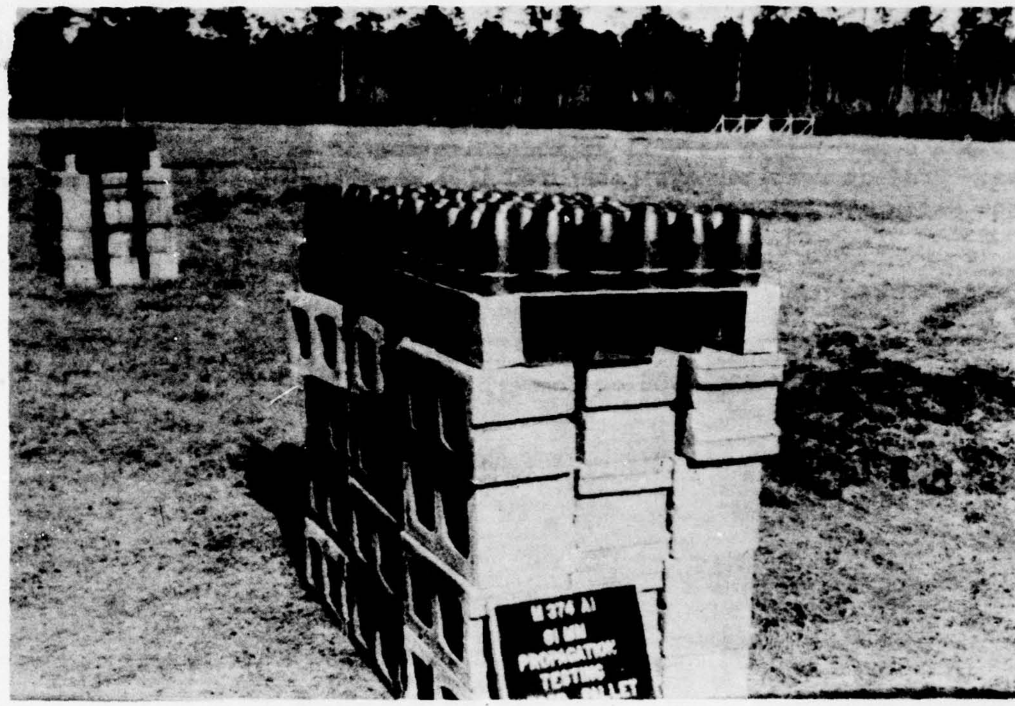


Figure 1 - 81mm projectile in 72-round pallets in test configuration prior to ignition

Tests were conducted in two phases: an exploratory phase during which probable minimum safe separation distance was determined by trial and error and, a confirmatory phase where sufficient tests were performed to statistically establish the probability of propagation of an explosive incident.

The confirmatory test phase established the minimum safe spacing for single projectiles as 45.72 centimeters (18 inches) with an upper limit of 5.1 percent probability of propagation at a 95 percent confidence limit. For the 72-projectile pallets, the minimum safe spacing was established as 9.14 meters (30 feet) with an upper limit of 6.8 percent probability of propagation at a 95 percent confidence limit.

BENEFITS

This project developed new safety criteria which will be integrated in Safety Regulatory Documents (AMCR 385-100) to permit construction of both functional and safe munitions manufacturing facilities.

The experimental verification that the safe separation distance for the 72-projectile pallets was 9.14 meters (30 feet) resulted in a 70 percent reduction in the explosive distance requirements as specified by AMCR 385-100.

IMPLEMENTATION

The results of this project will be applied to future evaluations of new plant construction as well as modernization of existing plant facilities. Project results have been used in the expansion and modernization of the Milan AAP and Lone Star AAP.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. J.R. Marsicovete, AV 880-3906 or Commercial (201) 328-3906.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 57T 4288 titled, "Explosive Safe Separation and Sensitivity Criteria" was completed in September 1978 for the US Army Armament Research and Development Command at a cost of $139,261.

BACKGROUND

This program was begun because of a concern that the design manuals in use were based on excessive extrapolation of data and over-design for the sake of safety. Prior efforts in this area were performed under project 576 4288 titled, "Explosive Safe Separation and Sensitivity Criteria" and projects 5XX 4201 titled, "Safety Engineering in Support of Ammunition Plants"

The effort described here was undertaken to provide additional data needed to upgrade processes and facilities in support of the Army's Modernization and Expansion Program.

SUMMARY

The objective of this project was to establish safe separation of explosive end items and in-process materials at various stages of their manufacturing process. Safe separation tests supported explosive items such as: CBU's; Grenade M42, (HE) GP; Mine, M56; Projectiles, 81mm M374A3, 155mm M107, 155mm M483, 155mm M549, 8-inch M106; Explosives, Compositions A5, A7, B-Flake, B-Riser Scrap, and TNT-Flake.

Only one example of project accomplishment will be described here to show typical types of sensitivity tests covered by this project. The example accomplishment is titled, "Determination of Minimum Non-Propagation Distance of 8-inch M106 HE Projectiles". A series of tests were conducted to establish the minimum non-propagation distances between 8-inch M106 HE projectiles loaded with 16.7 kilograms (38.8 pounds) of Composition B. Each projectile was supported above the ground surface by low density concrete blocks. The test results indicated that the minimum non-propagation distance for 8-inch M106 HE projectiles is 0.30 meter (1 foot) provided that aluminum shielding rods 7.6 centimeters (3.0 inches) in diameter and the same height as the projectiles are positioned vertically, in a straightline, between adjacent projectiles; see Figure 1. In the test the projectile marked "donor" is the one initiated while the two projectiles marked "acceptor" are shielded from the blast by three inch rods.

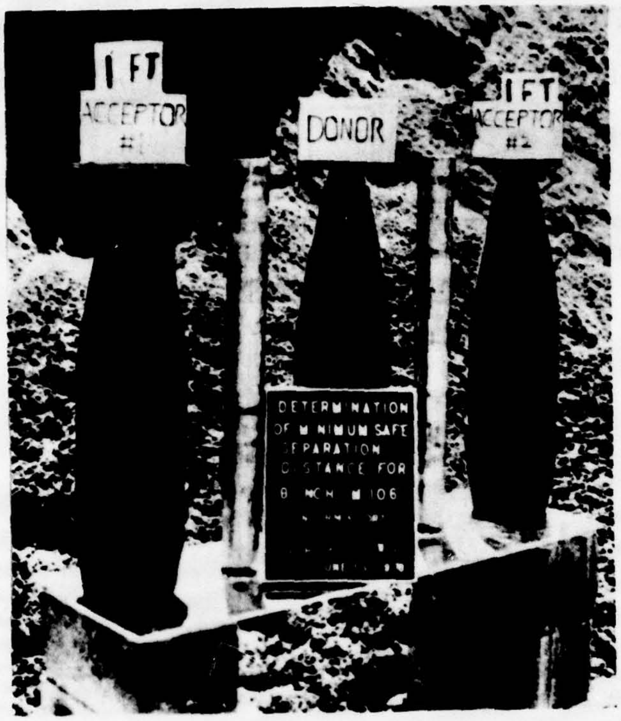


Figure 1 - Shielded Confirmatory Test Set-up

BENEFITS

This project provided new safety criteria which will be integrated into Safety Regulatory Documents (AMCR-385-100) to permit construction of both functional and safe munitions manufacturing facilities on a cost effective basis.

IMPLEMENTATION

Action is being taken to implement the information generated in the course of this program to new plant construction and to the modernization of existing plant facilities. Project results have been used in the modernization of the Iowa Army Ammunition Plant.

MORE INFORMATION

Additional information on this project is available from the Program Manager, Mr. J.R. Marsicovete, ARRADCOM, AV 880-3906 or Commercial (201) 328-3906.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 577 4288 titled, "Explosive Safe Separation and Sensitivity Criteria" was completed in May 1970 for the US Army Armament Research and Development Command at a cost of $566,669.

BACKGROUND

This program was begun because of a concern that the design manuals in use were based on excessive extrapolation of data and over-design for the sake of safety. Prior efforts in this area were performed under projects 576 4288 and 57T 4288 titled, "Explosive Safe Separation and Sensitivity Criteria" and projects 57X 4201 titled, "Safety Engineering in Support of Ammunition Plants".

The effort described here was undertaken to provide additional data needed to upgrade processes and facilities in support of the Army's Modernization and Expansion Program.

SUMMARY

The objective of this project was to develop new data to upgrade safety criteria for munition processes and facilities in support of Army's Modernization and Expansion Program. The data developed from this project was used to cost effectively provide maximum safety to personnel and equipment against explosion propagation. Three major areas of data development were evaluated: a) the safe separation of explosive end items and in-process materials, b) the critical and safe depths of bulk explosives on conveyor systems, and c) the sensitivity of explosives at various stages of their manufacturing process to impact from primary and secondary fragments.

Project accomplishments for this effort were too numerous to include in this report. One example selected to demonstrate typical accomplishments was the "Determination of Minimum Non-Propagation Distance Between Segments of 105mm M1 Projectile Composition B Riser Scrap".

In the tests performed for this example, Load-Assemble-Pack (LAP) plant conditions were simulated to determine minimum safe distances between 105mm M1 projectiles with Composition B riser scrap. Four test series were performed; namely, two riser scrap units without zamac funnels, four riser scrap units without funnels, two riser scrap units with funnels and four riser scrap units with funnels; see Figure 1. Test results indicated that the minimum non-propagating distances were 45.7 centimeters (18 inches) and

91.4 centimeters (36 inches) respectively, for configurations of two and four Composition B scrap risers without funnels, and 61 centimeters (24 inches) and 91.4 centimeters (36 inches) respectively, for configurations of two and four Composition B scrap risers with funnels.

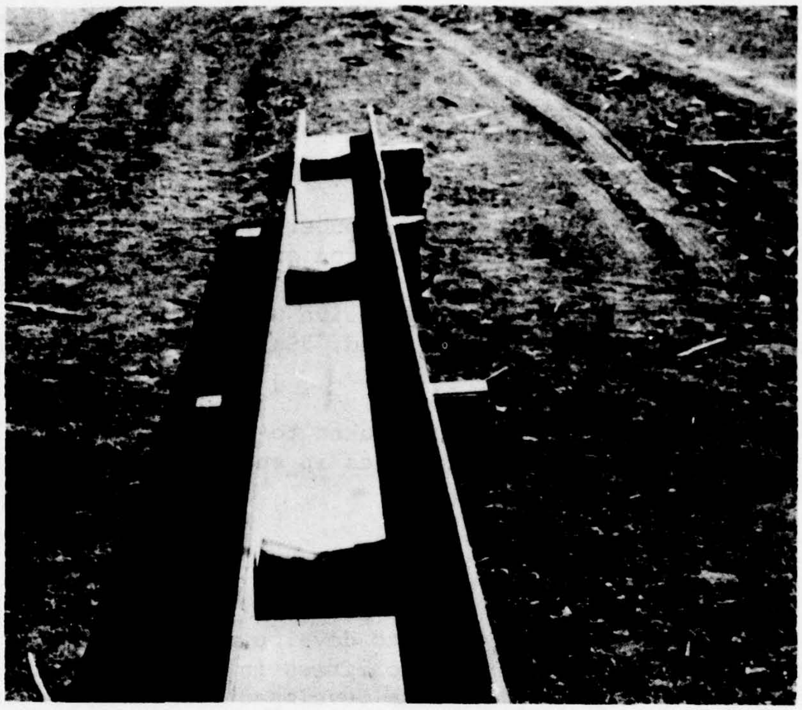


**Figure 1 - Test set up Phase.
Four risers with funnels.**

BENEFITS

This project developed new safety criteria which will be integrated into Safety Regulatory Documents (AMCR 385-100) to permit construction of both functional and safe munitions manufacturing facilities.

It was determined in the test example described herein that the safe distances for the projectiles with 1.13 kilograms (2.5 pounds) of Composition B ranged between 45.7 centimeters (18 inches) and 91.4 centimeters (36 inches). These distances are a reduction of 87-1/2 percent and 75 percent respectively from the explosive distance requirements specified by AMCR 385-100, Table 17.1.

IMPLEMENTATION

The results of this project will be applied to future designs of new plant construction as well as modernization of existing plant facilities. Project results have been applied to the modernization of the Lone Star Army Ammunition Plant.

MORE INFORMATION

Additional information on this project is available from the Project Manager, Mr. J.R. Marsicovete, ARRADCOM, AV 880-3906 or Commercial (201) 328-3906.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 576 4291 titled, "Blast Effects in the Munition Plant Environment" was completed by the US Army Armament Research and Development Command in December 1978 at a cost of $699,619.

BACKGROUND

Previously available criteria for the design of structures which could resist the effects of accidental HE explosions were limited to laced reinforced concrete elements and did not address criteria for all construction materials commonly used in the industry. Many of these commonly used materials may be applicable to construction of Load-Assemble-Pack (LAP) and explosive manufacturing facilities where accidental explosions would be only of the medium and low pressure magnitude. The intent of this effort was to provide additional criteria required for the safe design of structures constructed with all types of construction materials. As an example, window breakage which represents a major hazard, in an accidental explosion, to personnel in administration and other support facilities at Army Ammunition Plants was investigated. This project is a continuation of project 57X 4201 titled, "Safety Engineering in Support of Ammunition Plants".

SUMMARY

The objective of this project was to develop information and criteria required for the design of a complete LAP and explosive manufacturing facility. This information would broaden the scopes of safety manuals AMCR 385-100 and TM5-1300.

Project accomplishments for this effort were too numerous to include in this report. One example selected to demonstrate typical accomplishments was the "Blast Capacity Evaluation of Glass Windows and Aluminum Window Frames".

A series of eleven static tests, utilizing a hydraulic testing machine, and nine dynamic tests utilizing explosives, were performed to evaluate the blast-resistant capacity of tempered and regular glass windows and aluminum window frames used in buildings at Army Ammunition Plants. Window frames were found to be a critical element and it will be necessary in many cases to provide proper designs to insure that the required blast capacity of the glass is maintained. Test results indicate that tempered

glass held in rigid (i.e. wooden) window frames will resist breakage more than regular (untempered) glass mounted in the same type frames. Results also indicate that aluminum frames reduce glass blast capacity due to frame distortions. Charts are available for various recommended design criteria; an example chart is shown in Figure 1.

Glass	Peak incident or reflected pressure - kPa (psi)				
	Triangular load duration - msec				
	< 10	10 - 20	21 - 40	41 - 100	> 100
Tempered glass 3.18 mm (1/8 in)	21.0 (3.0)	17.0 (2.5)	14.0 (2.0)	10.0 (1.5)	6.9 (1.0)
Tempered glass 6.35 mm (1/4 in)	41.0 (6.0)	31.0 (4.5)	28.0 (4.0)	21.0 (3.0)	17.0 (2.5)
Tempered glass 9.52 mm (3/8 in)	55.0 (8.0)	48.0 (7.0)	41.0 (6.0)	34.0 (5.0)	28.0 (4.0)
Regular glass 3.18 mm (1/8 in)	2.8 (0.4)	2.1 (0.3)	1.7 (0.25)	1.0 (0.15)	0.7 (0.1)
Regular glass 6.35 mm (1/4 in)	4.8 (0.7)	4.1 (0.6)	3.4 (0.5)	2.8 (0.4)	2.1 (0.3)
Regular glass 9.52 mm (3/8 in)	6.2 (0.9)	5.5 (0.8)	4.8 (0.7)	4.1 (0.6)	3.4 (0.5)

Figure 1 - Recommended design criteria for maximum blast pressure capacity for glass mounted in rigid window frames

In addition, the size and shape of the glass fragments resulting from glass breakage of regular glass would represent a greater hazard to personnel than that of tempered glass, Figures 2 and 3.

BENEFITS

This project developed new, in-depth safety design criteria for blast capacity of glass windows, frame structures, single revetted barricades, pre-engineered buildings and cold-formed steel. These criteria were not available before and will be integrated into the existing regulatory document TM5-1300 to permit construction of both functional and safe munitons manufacturing facilities, utilizing construction materials commonly used in the industry.

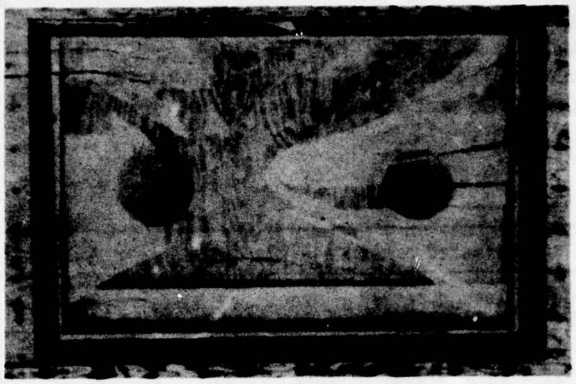


Figure 2 - Close-up of window showing jagged spear shaped nature of broken regular glass.

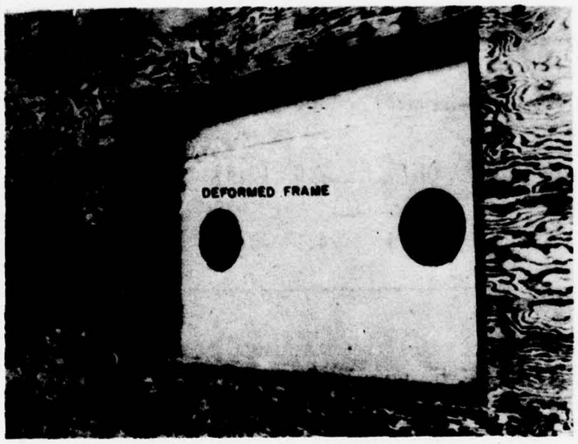


Figure 3 - Close-up of window showing irregular granules of broken tempered glass and deformed aluminum frame.

IMPLEMENTATION

Technical reports developed from this project are being used to update safety regulatory document TM5-1300. Information provided from this project has been used in designing the rebuild of the TNT line at Radford AAP and in designing the new plant at Mississippi AAP.

MORE INFORMATION

To obtain additional information, contact the Program Manager, Mr. J.R. Marsicovete, ARRADCOM, AV 880-3906 or Commercial (201) 328-3906.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 577 4416 titled, "Develop and Prove-Out of Alternate Manufacturing Processes for S&A (GEMSS)" was completed by the US Army Armament Research and Development Command in July 1978 at a cost of $120,000.

BACKGROUND

The current Ground Emplaced Mine Scattering System (GEMSS) Safe and Arming (S&A) housing design has an intricate internal configuration that is extremely difficult to fabricate from bar stock; see Figure 1. A new design S&A utilizing split zinc die cast housing and drawn/formed components was proposed by the GEMSS Producibility Engineering and Planning (PEP) contractor to replace the baselined S&A. This MMT project was to fabricate the S&A by an alternate process and test it to determine if this design should be included in the GEMSS Development Test (DT) II.

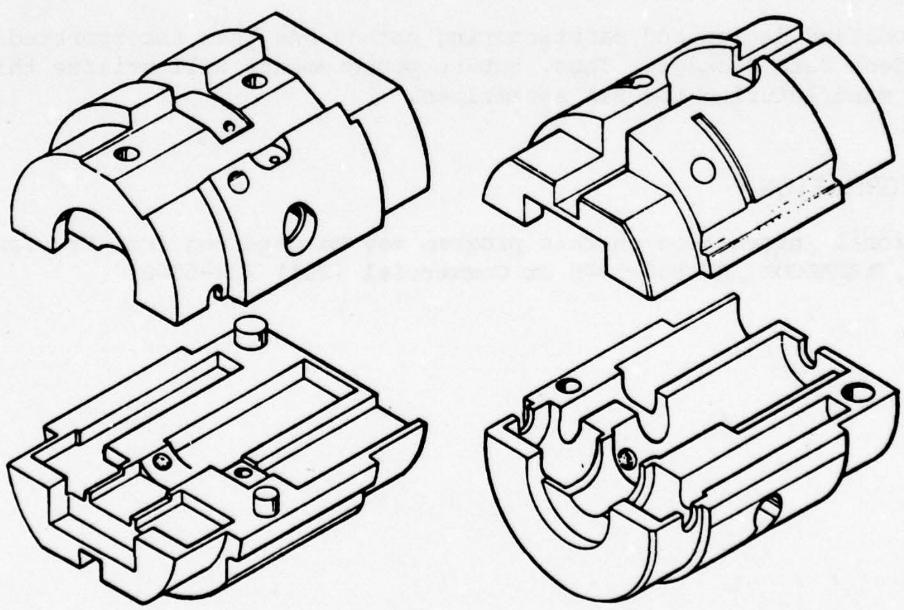


Figure 1 - Two-Piece GEMSS S&A Die-Cast Housing

SUMMARY

The objective of this project was to verify the PEP S&A design by fabricating a number of S&A's using the alternate process and then testing them in the XM74 and XM75 mines. Test results had to show no loss in safety or functional reliability for the new design.

A total of 164 PEP S&A's were fabricated and tested for function and safety. An additional 30 S&A's were subjected to rough handling test in inert XM74 mines. Mine tests which were conducted included jolt, jumble, drop test, safety and function at temperature extremes, thermal shock, transportation/vibration, and rough handling. All S&A assemblies successfully met the test acceptance criteria.

BENEFITS

Because of the tests conducted in this project, the new design S&A was included in DT II test of the GEMSS. This new design uses a split zinc die cast housing which is more reliable and will be less costly to manufacture in mass production quantities. A modified version of this design is being utilized in the GATOR and Modular Pack Mine System (MOPMS).

IMPLEMENTATION

The modified design and manufacturing method has been incorporated into the Tech Data Package. Thus, future procurements will utilize this method of manufacturing the S&A assemblies.

MORE INFORMATION

Additional information on this program may be obtained from Mr. Ian McKechnie, ARRADCOM, AV 880-5348 or Commercial (201) 328-5348.

Summary Report was prepared by Joe M. Carter, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

NON-METALS

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 774 5504 titled, "Production of Phosphazene Elastomers" was completed by the US Army Materials and Mechanics Research Center in November 1975 at a cost of $250,000.

BACKGROUND

This is part of a long term Army program designed to develop elastomers applicable for use over a wide temperature range and under a variety of other conditions. These elastomers were developed to be used in applications as O-rings, lip seals, coatings, and arctic fuel hoses. The objective of this project was to carry out rubber development for specific applications. Work was done at MERDC, Natick, Firestone, and Horizons Laboratory under the direction of AMMRC.

SUMMARY

Formulations for phosphazene elastomer polymers were sought which would be serviceable over the temperature range of -62°C to 204°C. The effects of reinforcing agents, vulcanization agents and stabilizers on compound properties were investigated. Efforts were made to optimize curing times and temperatues, stress-strain properties, hardness, compression set, tear and abrasion resistance, fluid, water, steam and acid resistance, and low temperature flexibility. A formula was developed for the compound with the best properties.

The polymer was processed with intensive mixing to incorporate the plasticizers which was then followed by rubber milling. Polymer formulations were readily worked on a rubber mill and when sheeted, had rough textured finishes. It was then found likely that the high processing temperatures (170°F) and a rubber mill with a low friction ratio or a calendar should produce smooth, uniform sheet stock. Plastics were extruded from the mixer without major difficulty, but they tended to crumble. The workability of the polymer at low process temperatures indicated it is capable of being injection molded and cold-formed with high-pressure equipment.

Compression molding was studied over a temperature range of 250°F to 450°F. Cooling the mold under pressure or quenching in cold water did not effect polymer appearance or texture. Molding temperature near 300°F for 15-30 minutes produced fairly uniform thin sheets (.070") that were translucent. Brown discolorations appeared at higher processing temperatures (400-450°F).

Experiments were conducted on the coating of stainless steel cable with elastomer compounds. A good quality coating was obtained by passing the cable through a crosshead extruder followed by vulcanization of the coating. These compounds have high limiting oxygen index values which adds to the applicability of these compounds.

In conclusion, different applications required different compounding, curing and processing techniques, and different physical properties. Material evaluation tests have not been correlated under actual service conditions.

BENEFITS

Polyphosphazenes are synthetic inorganic base polymers in contrast to most commercial polymers which are based on petroleum products. The successful large scale development of phosphazene elastomers and plastics could reduce the Army's dependence on petroleum based materials which might become less available in the future. Phosphazene elastomers are intended for application where present materials are unsatisfactory. This greater effectiveness will reduce the Army's cost for materials and maintenance in the intended areas of application.

IMPLEMENTATION

The materials development, processing, and test data furnished through the contract reports will be utilized in procuring test items, prototype seals, and O-rings fabricated from phosphazene elastomers. These data will also be used, in conjunction with in-house development and evaluation studies, to specify the optimum composition for the arctic fuel hose that will be produced in the subsequent project 776 5504.

MORE INFORMATION

More information on this project may be obtained by contacting Dr. Bob Singler at AMMRC, AV 995-3010 or Commercial (617) 923-3010.

Summary Report was prepared by Steve Albrecht, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project 774 5506 titled, "Improvement of Surface Finish of Ceramic Materials for Bearing Applications" was completed by US Army Materials and Mechanics Research Center in June 1976 at a cost of $75,000.

BACKGROUND

Ceramic roller bearings have a potentially longer service life than present steel roller bearings. Former ceramic roller bearings had an unreliable service life but are half as dense as steel roller bearings. Ceramic bearings with a long, reliable service life would be a significant advancement in the state-of-the-art. R&D studies have shown that, dependent upon the surface finish of the ceramic, an increase in life can be expected on the order of 10-20 times that of the best steel bearings.

SUMMARY

The purpose of this project was to establish manufacturing technology required to produce an optimum surface finish on ceramic materials to achieve maximum strength and performance of bearing materials.

Two types of hot-pressed silicon nitride, Norton Company HS-110 and NC-132, were evaluated in the program. The NC-132 silicon nitride had a higher chemical purity and improved mechanical properties, especially at temperatures greater than 1100°C.

A total of 25 different finishes were applied to the silicon nitride bars. The bars were grouped according to the final finishing operation. Variables in the finishing procedures included a) method of imparting final finish (grinding, honing, lapping, tumbling, gas polishing), b) abrasive type, diamond and silicon carbide wheels and various lapping compounds, c) depth of material removed per finishing step, d) abrasive grit size, e) abrasive bond type and grade hardness, and f) grinding wheel speed.

A Rolling Contact Fatigue test machine was developed to test the fatigue life of the silicon carbide. This machine put a bearing through 1.2 million stress cycles per hour. Early in the testing, fatigue lives were found to be much longer than anything previously encountered.

Ground finishes were essentially equal to the honed finishes with respect to fatigue performance. A honed finish, however, was necessary for a longer life of the steel part of the bearing. The smoothest finishes, produced by lapping procedures, did not in general, produce the longest fatigue lives. Superior finishing procedures were developed for straight and crowned roller geometries. Superior specimen concentricity did not produce a superior fatigue life.

BENEFITS

The benefits of this project included increased knowledge in the area of surface finishing methods. The benefits will be realized in turbine generator systems in aircraft and vehicles. Bearings will be useful for short term operation under starved lubrication conditions. Ceramic bearings will reduce cost, improve maintainability, and reliability.

IMPLEMENTATION

A technical data package was available to industry for competitive bidding on future contracts. Equipment, raw material specification, standardized process specifications, testing and quality control specifications were included in the data package. The results were not implemented. No physical implementation was planned.

MORE INFORMATION

Additional information on this project is available from Alan Crudo, AV 955-3523.or Commercial (617) 923-3010.

Summary Report prepared by Steve Albrecht, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

APPENDIX I

ARMY MMT PROGRAM OFFICES

ARMY MMT PROGRAM REPRESENTATIVES

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Rock Island, IL 61299 — AV: 793-5113

ARRADCOM
US Army Armament R&D Command
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ARRCOM
US Army Armament Materiel Readiness Command
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NARADCOM US Army Natick R&D Command ATTN: DRDNA-Z, Mr. Edward F. Levell Natick, MA 01760	C: AV:	617 653-1000, x2793/4 955-2349/2351
TARADCOM US Army Tank-Automotive R&D Command ATTN: DRDTA-KP, DRDTA-RCK, Mr. J. Chevalier Warren, MI 48090	C: AV:	313 573-2065/1814/2467 273-2065
TARCOM US Army Tank-Automotive Materiel Readiness Command ATTN: DRSTA-EB, Mr. Basel Armstead Warren, MI 48090	C: AV:	313 573-2485 273-2485
TECOM US Army Test & Evaluation Command ATTN: DRSTE-ME, Mr. Grover Shelton Aberdeen Proving Ground, MD 21005	C: AV:	301 278-2170/3677 283-2170/3677

APPENDIX II

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PM, HAWK, Attn: DRCPM-HA (MICOM)
PM, Heavy Equipment Transporter (HET), Attn: DRCPM-HT (TARCOM)
PM, Heliborne Laser Fire and Forget (HELLFIRE) Missile System, Attn: DRCPM-HE (MICOM)

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Project/Product Managers (Cont'd):

PM, High Energy Laser System, Attn: DRCPM-HEL (MICOM)
PM, Improved TOW Vehicle, Attn: DRCPM-ITV (TARADCOM)
PM, LANCE, Attn: DRCPM-LC (MICOM)
PM, M60 Tank Development, Attn: DRCPM-M60TD (TARCOM)
PM, M60 Tank Production, Attn: DRCPM-M60TP (TARCOM)
PM, M110E2 Weapon System, Attn: DRSAR-HA (ARRCOM)
PM, M113/M113A1 Family of Vehicle Readiness, Attn: DRCPM-M113 (TARCOM)
PM, MPBM&E, Attn: DRCPM-PBM-T-PA, Mr. S. Karlin
PM, Mobile Electric Power, Attn: DRCPM-MEP (Springfield, VA)
PM, Multi-Service Communications Systems, Attn: DRCPM-MSCS (CORADCOM)
PM, Navigation Control Systems (NAVCON), Attn: DRCPM-NC (ERADCOM)
PM, Nuclear Munitions, Attn: DRCPM-NUC (ARRADCOM)
PM, PATRIOT, Attn: DRCPM-MD (MICOM)
PM, PERSHING, Attn: DRCPM-PE (MICOM)
PM, Remotely Monitored Battlefield Sensor Systems (REMBASS), Attn: DRCPM-RBS (ERADCOM)
PM, 2.75 Rocket System, Attn: DRCPM-RK (MICOM)
PM, SATCOM, Attn: DRCPM-SC (ERADCOM)
PM, Selected Ammunition, Attn: DRCPM-SA (ARRADCOM)
PM, Signal Intelligence/Electronic Warfare (SIGINT/EW), Attn: DRCPM-SIEW (CERCOM)
PM, Single Channel Ground and Airborne Radio Subsystem (SINCGARS), Attn: DRCPM-GARS (CORADCOM)
PM, Smoke/Obscurants (SMOKE), Attn: DRCPM-SMK (APG)
PM, Special Electronic Mission Aircraft (SEMA), Attn: DRCPM-AE (TSARCOM)
PM, Stand-off Target Acquisition System, Attn: DRCPM-STA (ERADCOM)
PM, STINGER, Attn: DRCPM-MP (MICOM)
PM, TOW-DRAGON, Attn: DRCPM-DT (MICOM)
PM, Training Devices, Attn: DRCPM-TND (Orlando, FL)
PM, US ROLAND, Attn: DRCPM-ROL (MICOM)
PM, VIPER, Attn: DRCPM-VI (MICOM)
PM, XM-1 Tank System, Attn: DRCPM-GCM (TARADCOM)

Project Officers:

PO, M60A1 Tank Camouflage Pilot Program, Attn: DRXFB-RT
PO, SLUFAE/SLUMINE, Surface Launch Unit Fuel Air Explosive (SLUFAE) Mine Neutralization System/Surface Launched Unit Mine (SLUMINE) Dispensing System, Attn: DRDME-NS (Ft. Belvoir)
PO, Stand-Off Target Acquisition/Attack System (SOTAS), Attn: DRSEL-CT
PO, Test, Measurement, and Diagnostic Equipment, Attn: DRCRE-T (DARCOM)
PO, Tactical Shelters, Attn: DRXNM-UBS

Major Subcommands:

Cdr, ARRCOM, Attn: DRSAR-CG
Cdr, ARRADCOM, Attn: DRDAR
Cdr, AVRADCOM, Attn: DRDAV
Cdr, CERCOM, Attn: DRSEL
Cdr, APG, Attn: STEAP-MT-M, Mr. J.L. Sanders

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Cdr, MICOM, Attn: DRSMI
Cdr, TARADCOM, Attn: DRDTA
Cdr, TARCOM, Attn: DRSTA
Cdr, TECOM, Attn: DRSTE
Cdr, TSARCOM, Attn: DRSTS
Cdr, MERADCOM, Attn: DRDME
Cdr, NARADCOM, Attn: DRDNA
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Arsenals: (6 cys each)
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Cdr, Rock Island Arsenal (RIA), Attn: SARRI-CO
Cdr, Rocky Mountain Arsenal (RMA), Attn: SARRM-IS
Cdr, Watervliet Arsenal (WVA), Attn: SARWV

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Cdr, Hawthrone AAP, Attn: SARHW
Cdr, Holston AAP, Attn: SARHO
Cdr, Indiana AAP, Attn: SARIN
Cdr, Iowa AAP, Attn: SARIO
Cdr, Kansas AAP, Attn: SARKA
Cdr, Lake City AAP, Attn: SARLC
Cdr, Lone Star AAP, Attn: SARLS
Cdr, Longhorn AAP, Attn: SARLO
Cdr, Louisiana AAP, Attn: SARLA
Cdr, McAlester AAP, Attn: SARMC-FD
Cdr, Milan AAP, Attn: SARMI
Cdr, Mississippi AAP, Attn: SARMS
Cdr, Radford AAP, Attn: SARRA
Cdr, Riverbank AAP, Attn: SARRB
Cdr, Scranton AAP, Attn: SARSC

Depots:
Cdr, Anniston Army Depot, Attn: SDSAN-MD
Cdr, Corpus Christi Army Depot, Attn: SDSCC-MPI
Cdr, Letterkenny Army Depot, Attn: SDSLE-MM
Cdr, New Cumberland Army Depot, Attn: SDSNC-ME
Cdr, Red River Army Depot, Attn: SDSRR-MO
Cdr, Sacramento Army Depot, Attn: SDSSA-MPE
Cdr, Seneca Army Depot, Attn: SDSSE-OP
Cdr, Sharpe Army Depot, Attn: SDSSH-R

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Depots (Cont'd)
Cdr, Sierra Army Depot, Attn: SDSSI-EM
Cdr, Tobyhanna Army Depot, Attn: SDSTO-M
Cdr, Tooele Army Depot, Attn: SDSTE-MAN

DARCOM Laboratories and Schools:
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Cdr, Army Harry Diamond Labs (HDL), Attn: DELHD (6 cys)
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Dir, Army Materials and Mechanics Research Ctr. (AMMRC), Attn: DRXMR, DRXMR-M (6 cys)
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Cdr, Army Weapons Support Ctr, Crane, IN 47522
Cdr, Foreign Science and Technology Ctr. (FSTC), Attn: DRXST-MT1, Mr. James Wamsley
Dir, Installations and Services Activity (I&SA), Attn: DRCIS
Cdr, Night Vision Labs (NVL), Attn: DRSEL-NV-PA/IO

MT Representatives:
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Cdr, CERCOM, Attn: DRSEL-LE-R, Mr. Martin Ides
Cdr, CORADCOM, Attn: DRDCO-PPA-TP, Mr. Al Feddeler/Sam Esposito/Burton Resnic
Cdr, ERADCOM, Attn: DELET-R, Mr. Joseph Key/Bernard Reich
Cdr, MERADCOM, Attn: DRDME-UPE, Mr. S.O. Newman (9 cys)
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Cdr, Naval Surface Weapons Ctr/White Oak Lab, Attn: Code E345, Mr. Chas McFann
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Society of Manufacturing Engineers
Attn: Mr. Bernard Sallot, One SME Drive, P.O. Box 930, Dearborn, MI 48128
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American Society for Testing and Materials
Attn: Mr. Samuel F. Etris, Special Assistant, 1916 Race Street, Philadelphia, PA 19103
Cast Metal Federation
Attn: Mr. William E. Gephardt, Chairman, Govt. Supply Committee, 4870 Packard Road, Niagara Falls, NY 14304